

Global Ocean Monitoring: Recent Evolution, Current Status, and Predictions

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February 6, 2009

<http://www.cpc.ncep.noaa.gov/products/GODAS/>

Outline

- **Overview**
- **Recent highlights**
 - **Pacific/Arctic Ocean**
 - **Indian Ocean**
 - **Atlantic Ocean**
- **CFS SST Predictions**

Overview

- **Pacific Ocean**

- La Niña conditions ($\text{NINO3.4} < -0.5^{\circ}\text{C}$) persisted in January 09, and are expected to continue into Spring 2009.
- Negative PDO-like SST pattern has persisted in North Pacific for 17 months with yearly mean value as the lowest since 1971.
- Extremely strong above-normal upwelling has persisted along the west coast of North America for two months.

- **Indian Ocean**

- Positive SST anomalies presented in the southern Indian Ocean and the Arabian Sea.
- The tropical Indian Ocean SSTs are close to normal.

- **Atlantic Ocean**

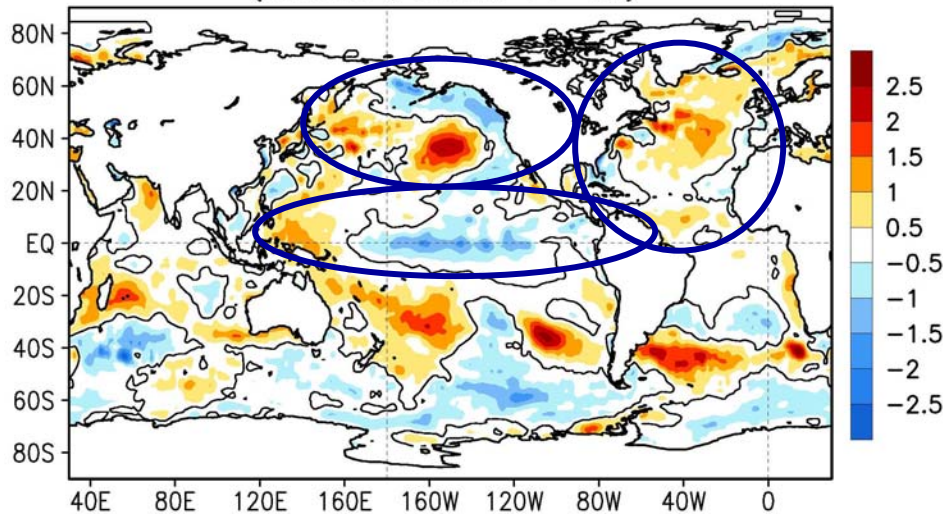
- Positive SST anomalies presented in mid-latitude North Atlantic and tropical Atlantic.

- **Arctic Ocean**

- Ice concentration remains much below-normal, with the ice growth slowing down in later January.

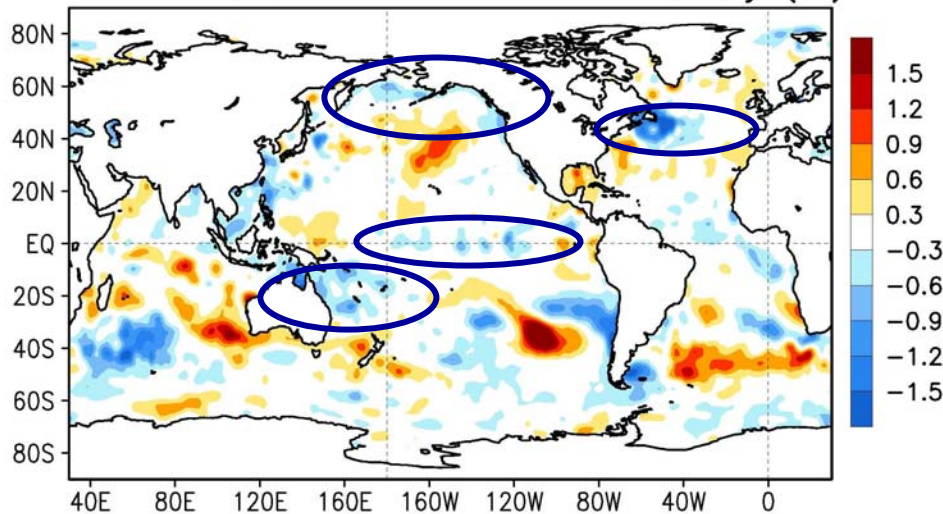
Global SST Anomaly ($^{\circ}\text{C}$) and Anomaly Tendency

JAN 2009 SST Anomaly ($^{\circ}\text{C}$)
(OISST.v2, Climo. 71-00)



- Negative PDO-like SST pattern in North Pacific.
- Positive SSTA in the northern and tropical North Atlantic.
- La Niña Conditions in the tropical Pacific.

JAN 2009 – DEC 2008 SST Anomaly ($^{\circ}\text{C}$)

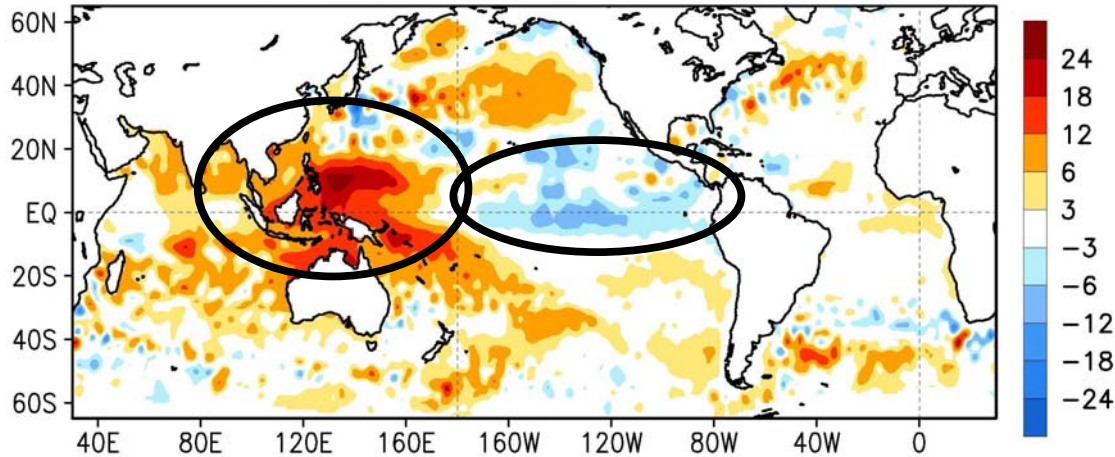


- Negative SSTA deepened in the central tropical Pacific, Bering Sea and Gulf of Alaska.
- Positive SSTA weakened near SPCZ and North Atlantic.
- Large SSTA tendency in the midlatitude Southern Oceans where the mixed layer is seasonally shallow.

Fig. G1. Sea surface temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

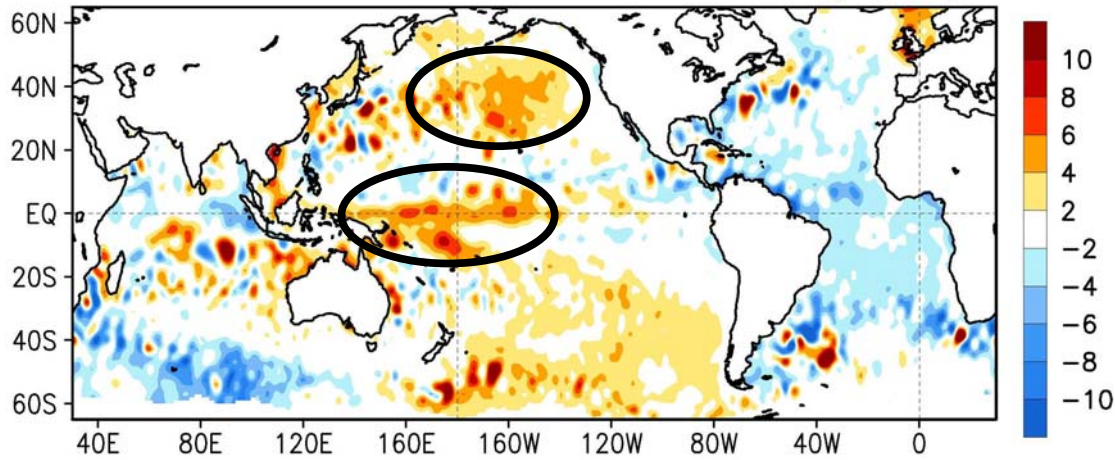
Global SSH Anomaly (cm) and Anomaly Tendency

JAN 2009 SSH Anomaly (cm)
(AVISO Altimetry, Climo. 93–05)



- Negative SSHA in the central and eastern equatorial Pacific.
- Positive SSHA in most of the Indian Ocean and western Pacific.

JAN 2009 – DEC 2008 SSH Anomaly (cm)

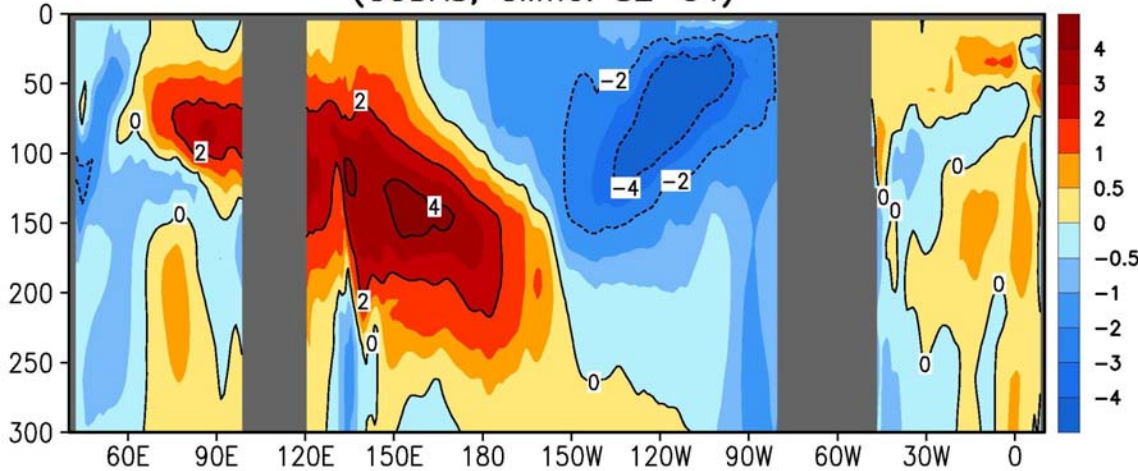


- Positive SSHA in the equatorial western Pacific enhanced and expanded eastward.
- Positive SSHA in the central North Pacific enhanced.

Fig. G2. Sea surface height anomalies (top) and anomaly tendency (bottom). Data are derived from <http://www.aviso.oceanobs.com>. Anomalies are departures from the 1993-2005 base period means.

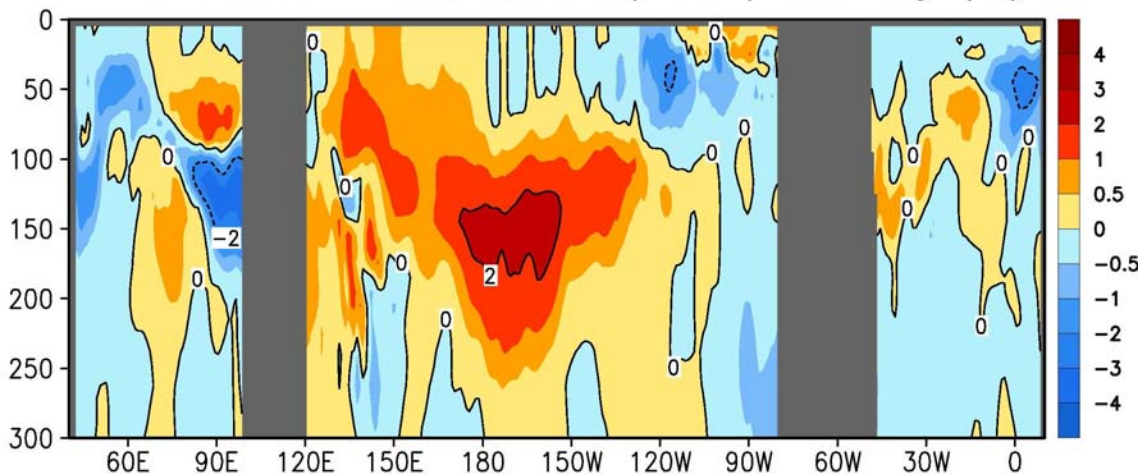
Longitude-Depth Temperature Anomaly and Anomaly Tendency in 2°S-2°N

JAN 2009 Eq. Temp Anomaly (°C)
(GODAS, Climo. 82-04)



- Positive (negative) subsurface temperature anomalies about 4°C presented in the equatorial western (central-eastern) Pacific.
- Positive subsurface temperature anomalies about 2°C in the eastern equatorial Indian Ocean.

JAN 2009 – DEC 2008 Eq. Temp Anomaly (°C)



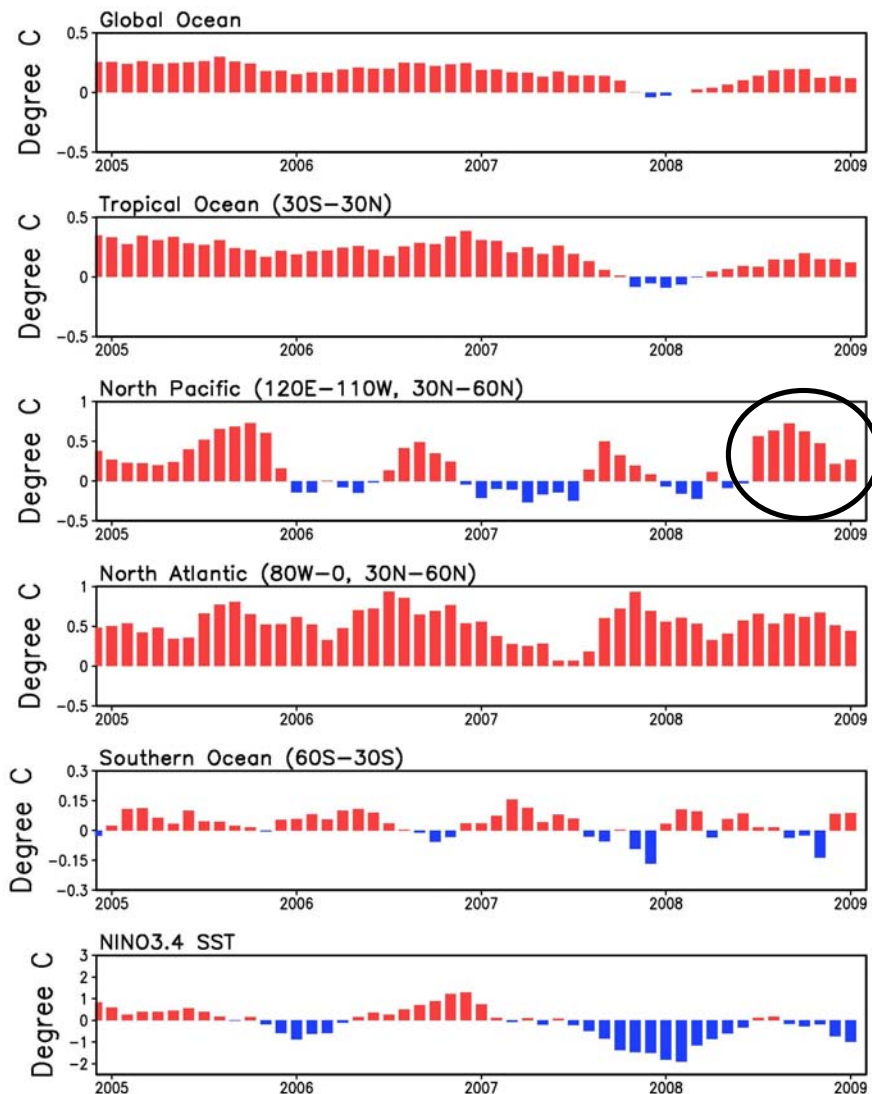
- Positive subsurface temperature anomalies in the equatorial western Pacific enhanced and expanded westward.

Fig. G3. Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP's global ocean data assimilation system which assimilates oceanic observations into an oceanic GCM. Anomalies are departures from the 1982-2004 base period means.

Monthly Time Series

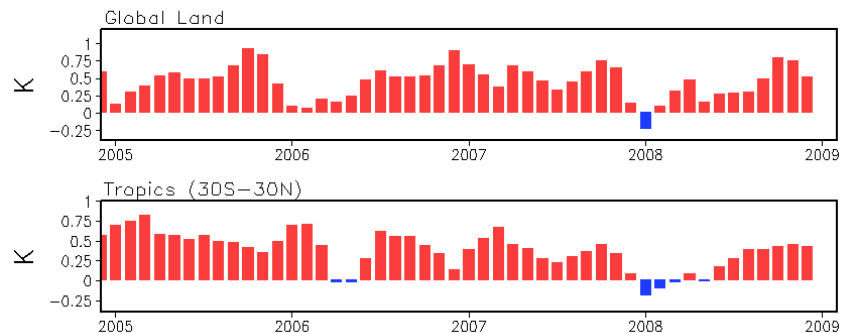
Sea Surface Temperature

Monthly SST Time Series (OISST.v2, Climo. 1971–2000)



CAMS Land Temperature

CAMS Temperature (Climo. 1982–2004)
(3–Month running mean)

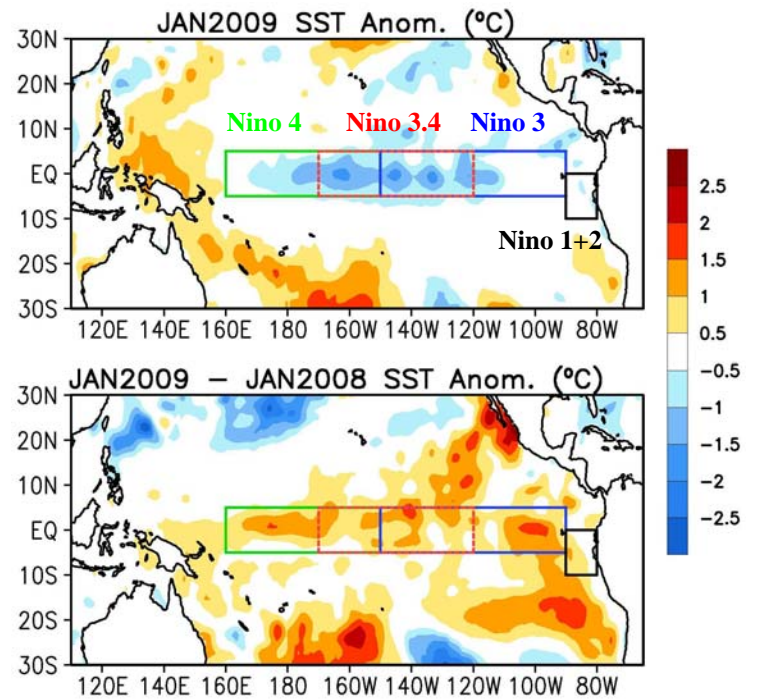
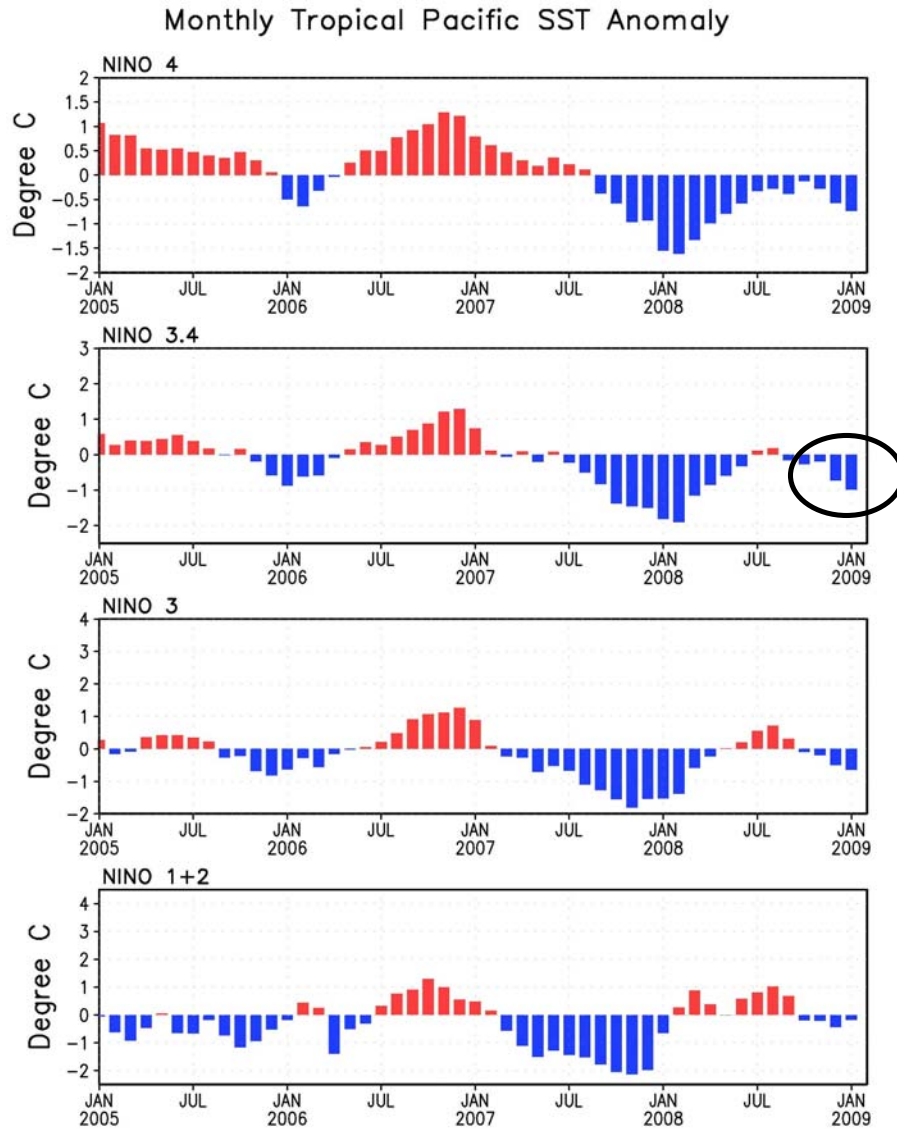


- Global mean SSTA and land temperature anomalies persisted.
- Tropical land temperature continues to be above-normal in response to the above-normal tropical ocean SST.
- Weak positive SSTA in North Pacific continued.
- Large positive SSTA in North Atlantic has persisted from September 07 to present.
- Negative NINO 3.4 SST met NOAA's La Nina definition ($NINO\ 3.4 < -0.5^{\circ}C$) since Dec 2008.

Fig. BU. Sea surface temperature (SST) anomalies (left) and surface air temperature anomalies (right) average for selected regions. Due to larger variability, the surface air temperature anomalies have a 3-month running mean applied. Anomalies were computed with respect to the 1971-2000 base period means.

Tropical Pacific Ocean

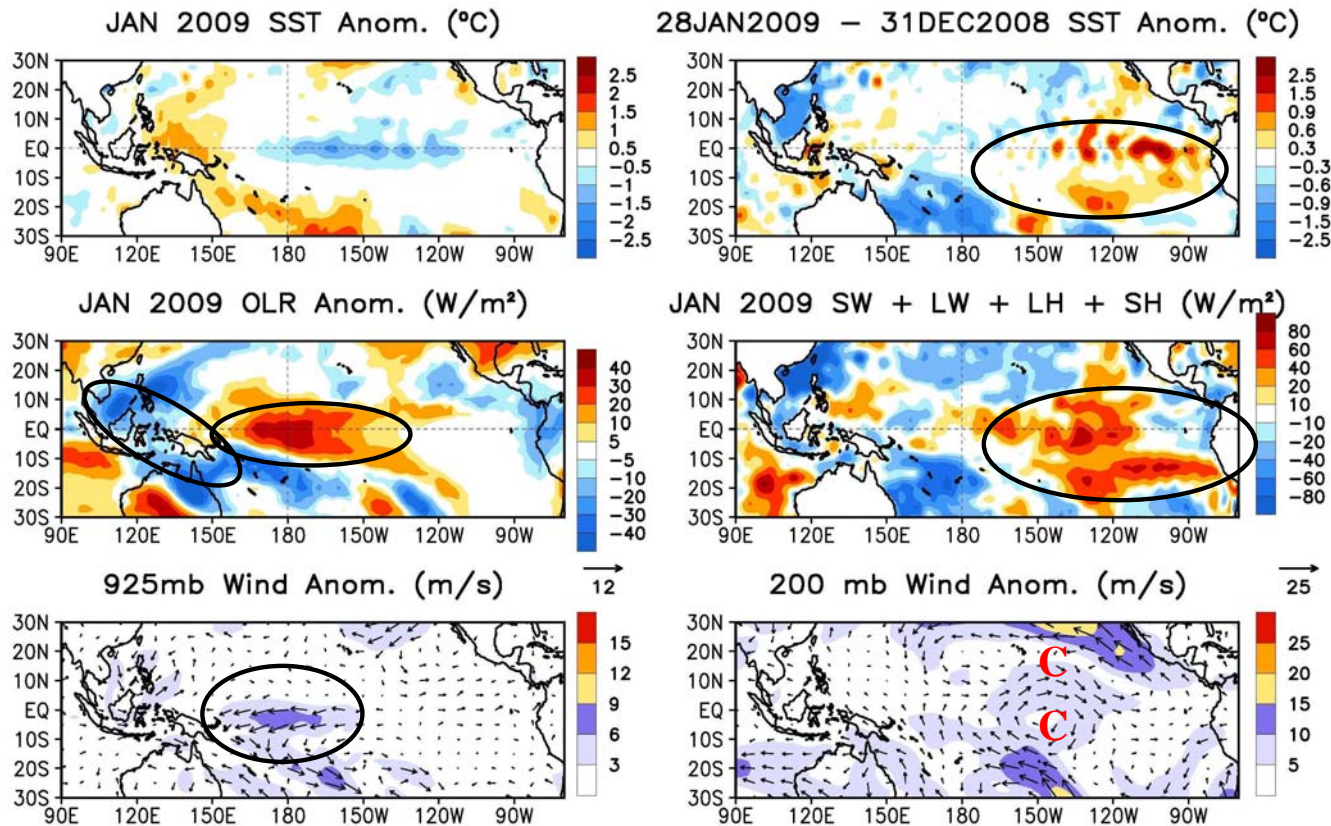
Evolution of Pacific NINO SST Indices



- La Niña conditions (NINO3.4 < -0.5°C) developed since December 2008, and are expected to continue into spring 2009 – NOAA's "ENSO Diagnostic Discussion".
- All NINO indices are below-normal.

Fig. P1a. Nino region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

Tropical Pacific: SST Anom., SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Winds



- Convection suppressed (enhanced) in the central tropical Pacific (Maritime Continent).
- Low-level easterly wind anomalies in the central tropical Pacific.
- Upper-level twin cyclones in subtropics near 150W, consistent with La Nina conditions.

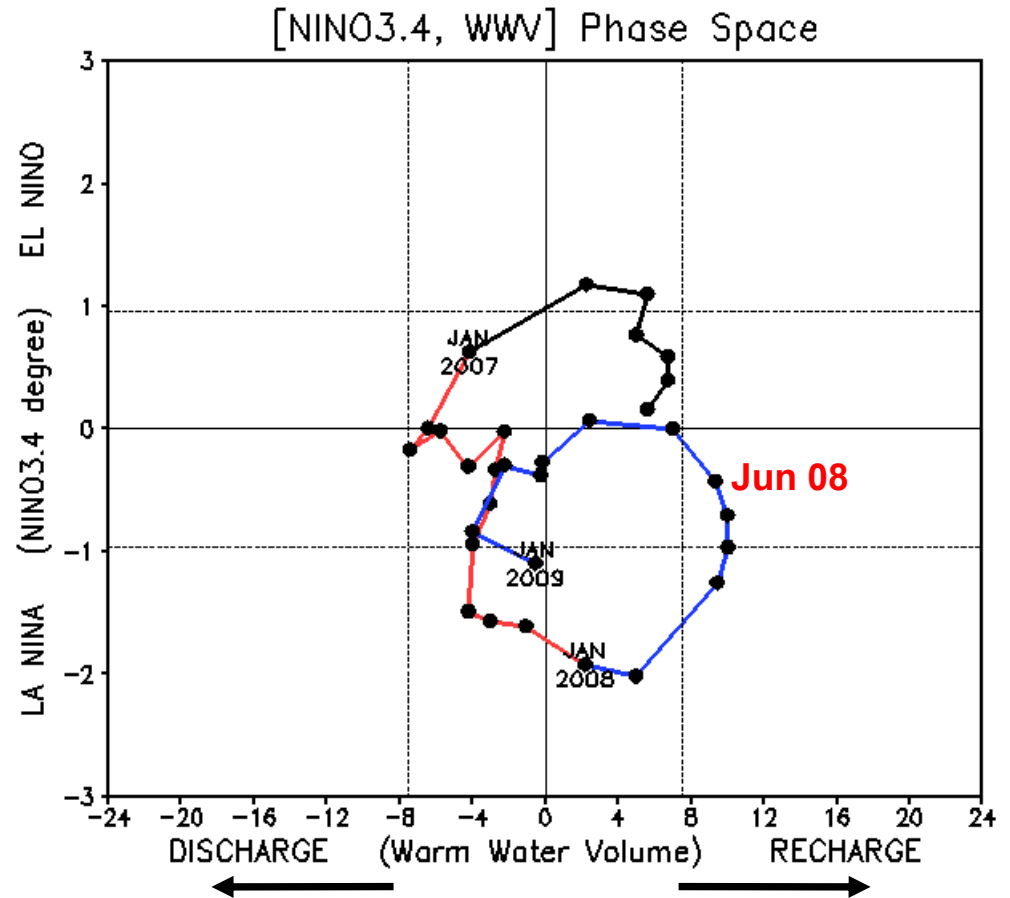
Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, winds and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1979-1995 base period means except SST anomalies are computed with respect to the 1971-2000 base period means.

Warm Water Volume (WWV) and NINO3.4 Anomalies

- WWV is defined as average of depth of 20°C in [120°E-80°W, 5°S-5°N] (Meinen and McPhaden, 2000).

- Since WWV is intimately linked to ENSO variability (Wyrтки 1985; Jin 1997), it is useful to monitor ENSO in a phase space of WWV and NINO3.4 (Kessler 2002).

- Increase (decrease) of WWV indicates recharge (discharge) of the equatorial oceanic heat content.



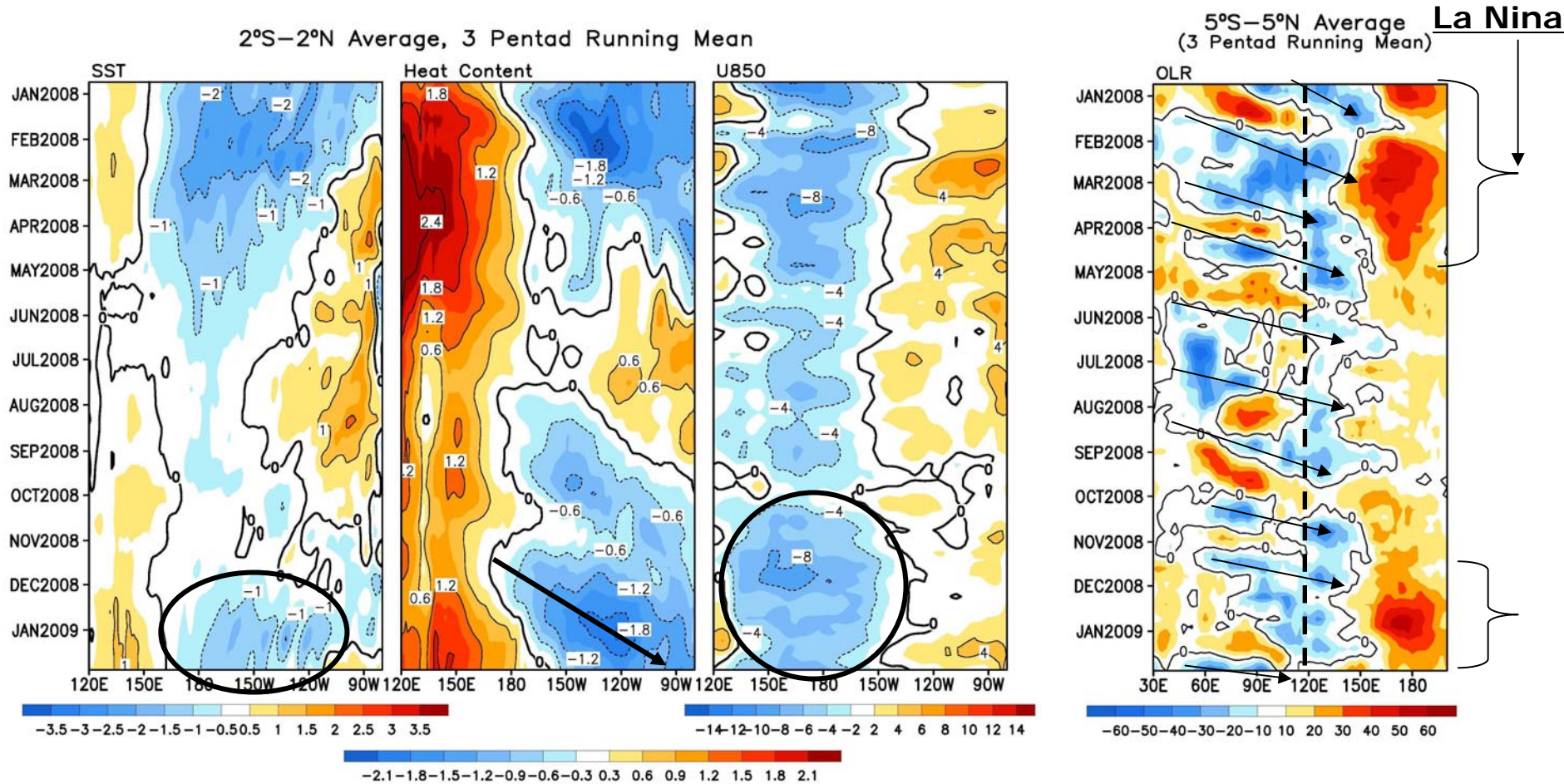
- Warm Water Volume (WWV) has discharged from June to December 08, but recharged in from December 08 to January 09 and is close to zero now.

- Both NINO3.4 and WWV have been below-normal since September 08.

Fig. P3. Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20°C in [120°E-80°W, 5°S-5°N] calculated with the NCEP's global ocean data assimilation system. Anomalies for WWV (NINO 3.4) are departures from the 1982-2004 (1971-2000) base period means.

Evolution of Equatorial Pacific SST ($^{\circ}\text{C}$), 0-300m Heat Content ($^{\circ}\text{C}$),

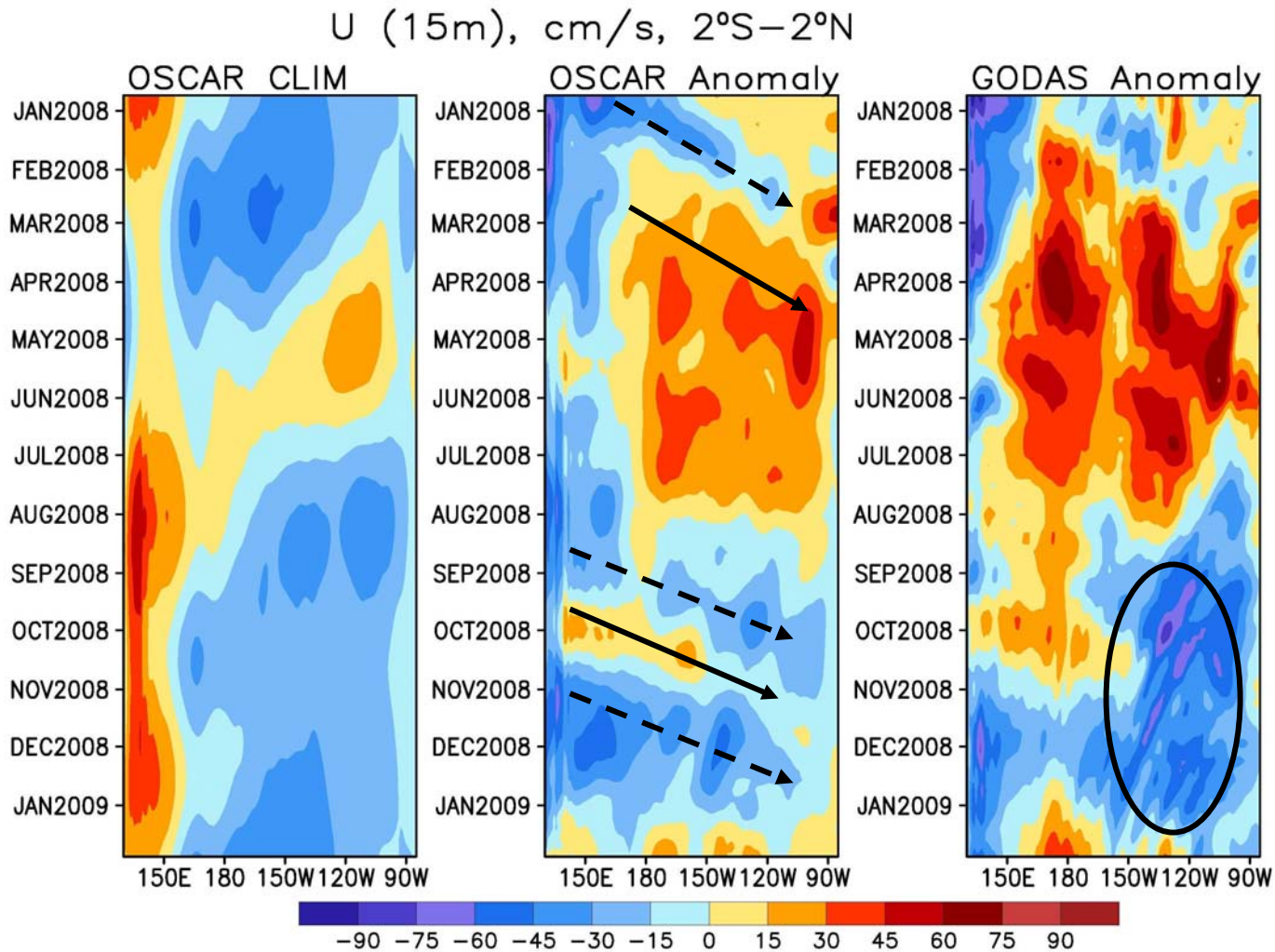
850-mb Zonal Wind (m/s), and OLR (W/m^2) Anomaly



- Below-normal SST in the central tropical Pacific since Dec 08.
- Eastward propagation of heat content anomalies along the equator in last two months.
- Enhanced easterly wind anomalies in late January were associated with enhanced convection in the tropical Indian Ocean.

Fig. P4. Time-longitude section of anomalous pentad sea surface temperature (left), upper 300m temperature average (heat content, middle-left), 850-mb zonal wind (U850, middle-right) averaged in 2 $^{\circ}\text{S}$ -2 $^{\circ}\text{N}$ and Outgoing Long-wave Radiation (OLR, right) averaged in 5 $^{\circ}\text{S}$ -5 $^{\circ}\text{N}$. SST is derived from the NCEP OI SST, heat content from the NCEP's global ocean data assimilation system, U850 from the NCEP CDAS. Anomalies for SST, heat content and U850/OLR are departures from the 1971-2000, 1982-2004, 1979-1995 base period pentad means respectively.

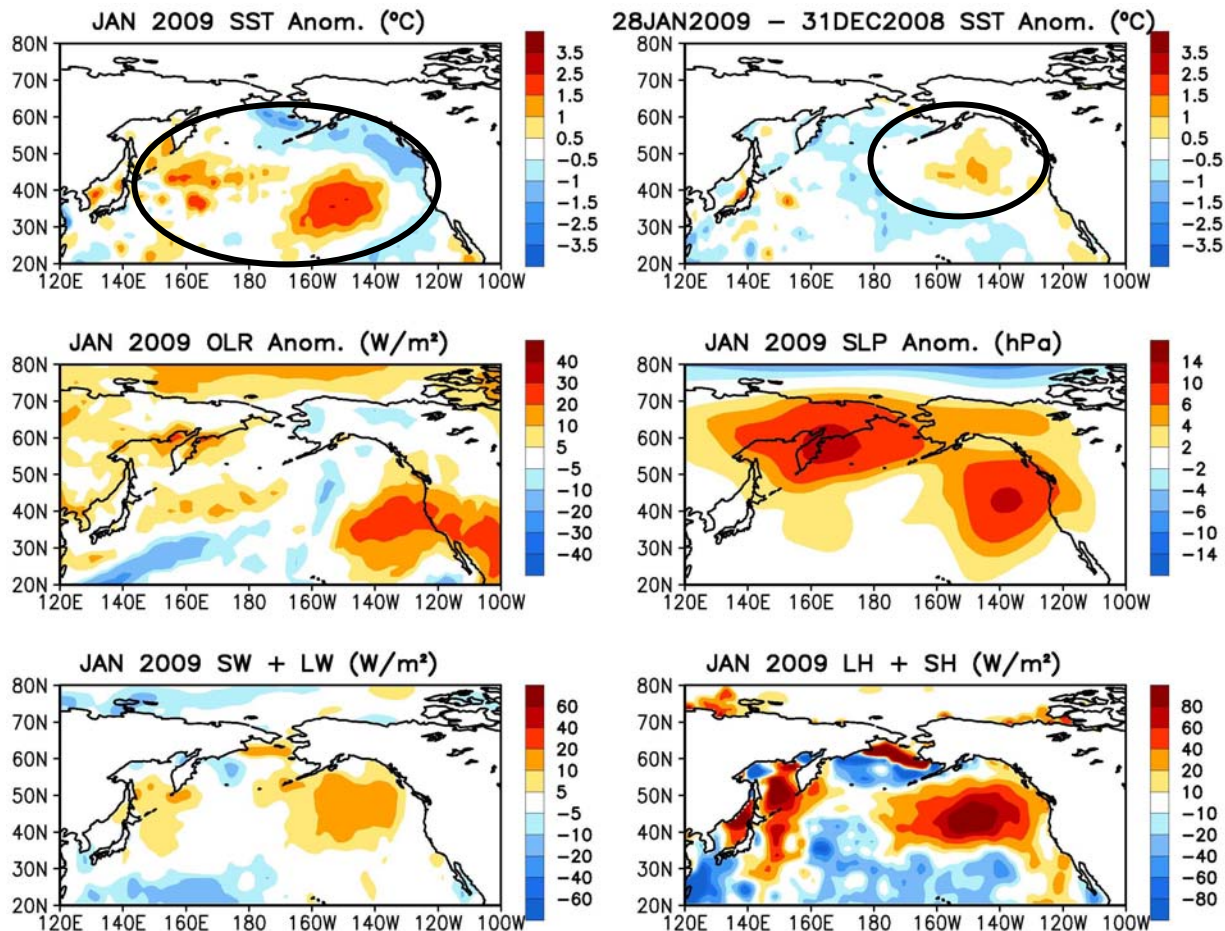
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



- Eastward propagation of negative (dashed line) (positive, solid line) surface zonal current anomalies were associated with upwelling (downwelling) oceanic Kelvin waves.
- Surface zonal current anomaly switched to positive in mid-Jan 09.
- Negative surface zonal current anomalies of GODAS in the E. tropical Pacific were too strong compared to OSCAR currents.

North Pacific & Arctic Ocean

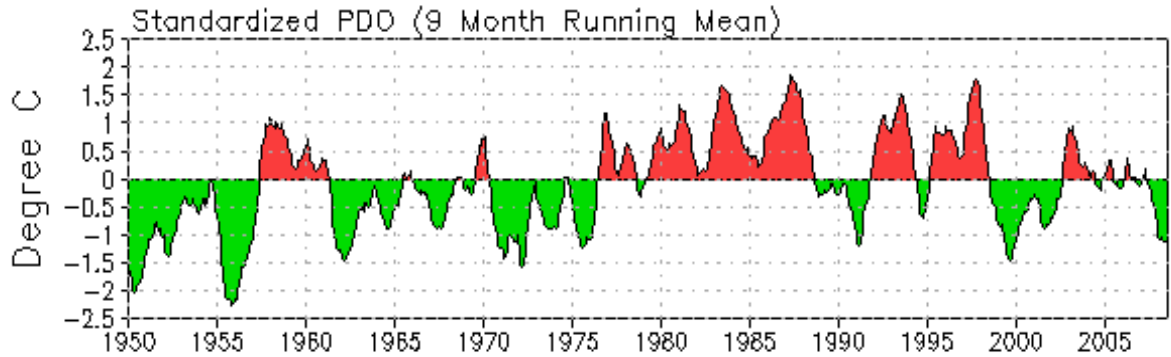
North Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx



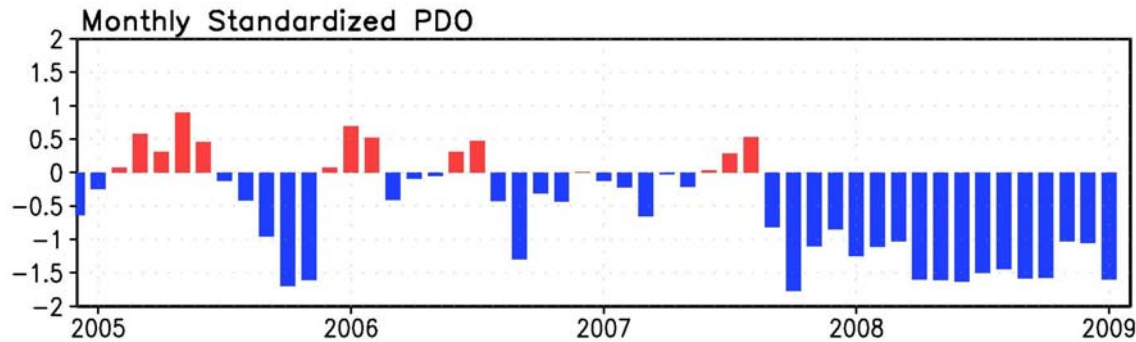
- Negative PDO-like SST pattern presented in North Pacific.
- SST increased in the eastern North Pacific, consistent with the turbulent flux anomalies and anomalous high sea level pressure.
- Above-normal sea level pressure in the North Pacific was in favour of coastal upwelling along the west coast of North America (slide 18).

Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible heat flux anomalies (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, sea surface pressure and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1979-1995 base period means except SST anomalies are computed with respect to the 1971-2000 base period means.

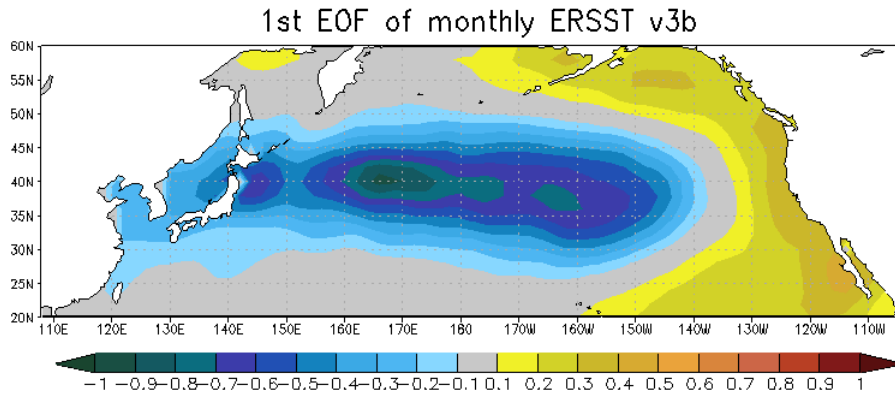
PDO index



PDO index at the lowest value since 1999.



PDO index below-average since September 2007.

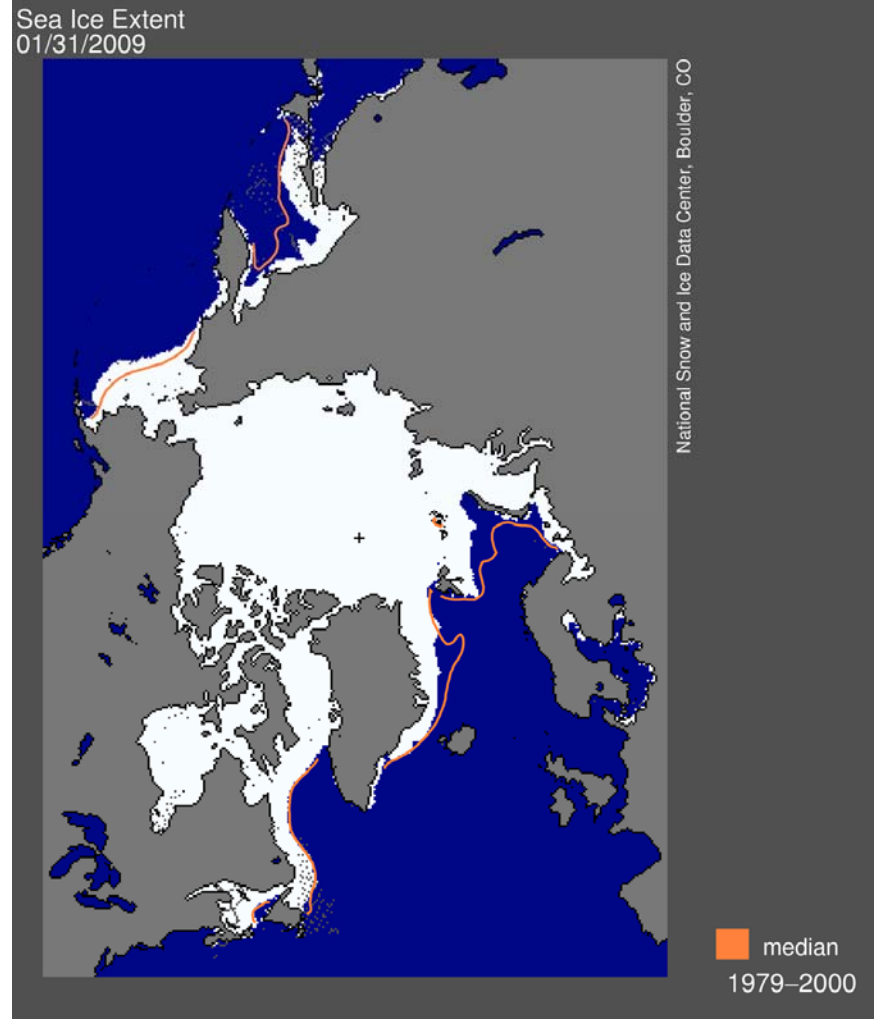
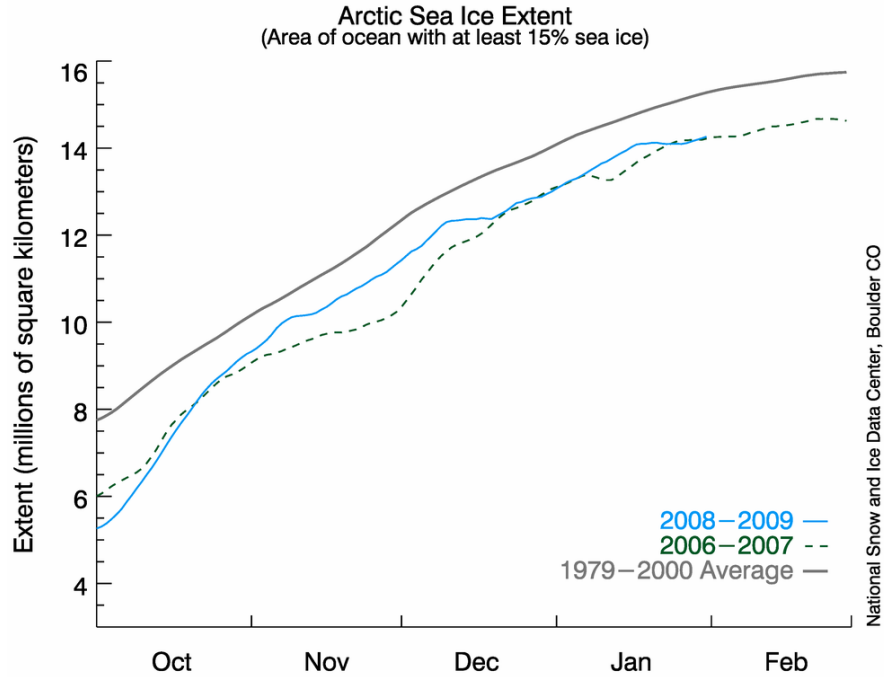


- Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.

- The PDO index differs slightly from that of JISAO, which uses a blend of UKMET and OIv1 and OIv2 SST.

Arctic Sea Ice

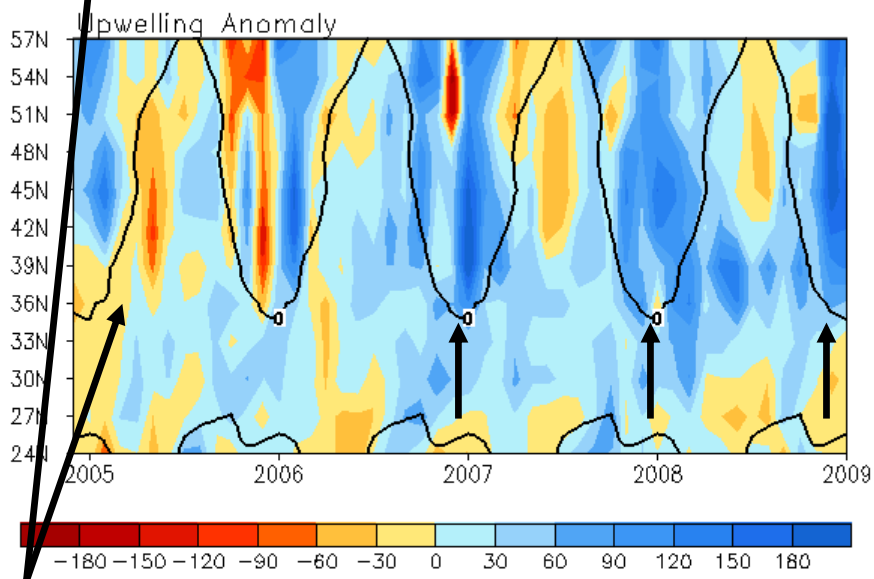
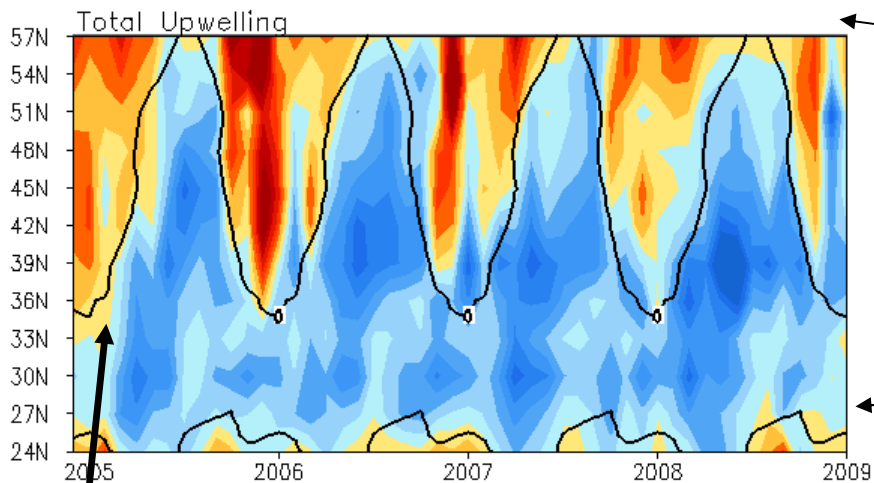
National Snow and Ice Data Center
<http://nsidc.org/arcticseaicenews/index.html>



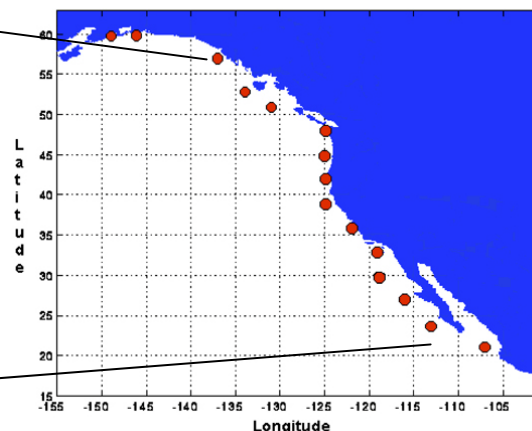
- Sea ice extent remains well below-normal.
- Arctic sea ice growth slowed during mid-January.

North America Western Coastal Upwelling

Monthly Coastal Upwelling for West Coast North America
($\text{m}^3/\text{s}/100\text{m}$ coastline)



Standard Positions of Upwelling Index Calculations



- 2008 upwelling season is above-normal.
- The above-normal upwelling season is associated with the negative PDO phase.
- Upwelling has been extremely strong during winters of 2007 and 2008, and likely continue in winter of 2009.

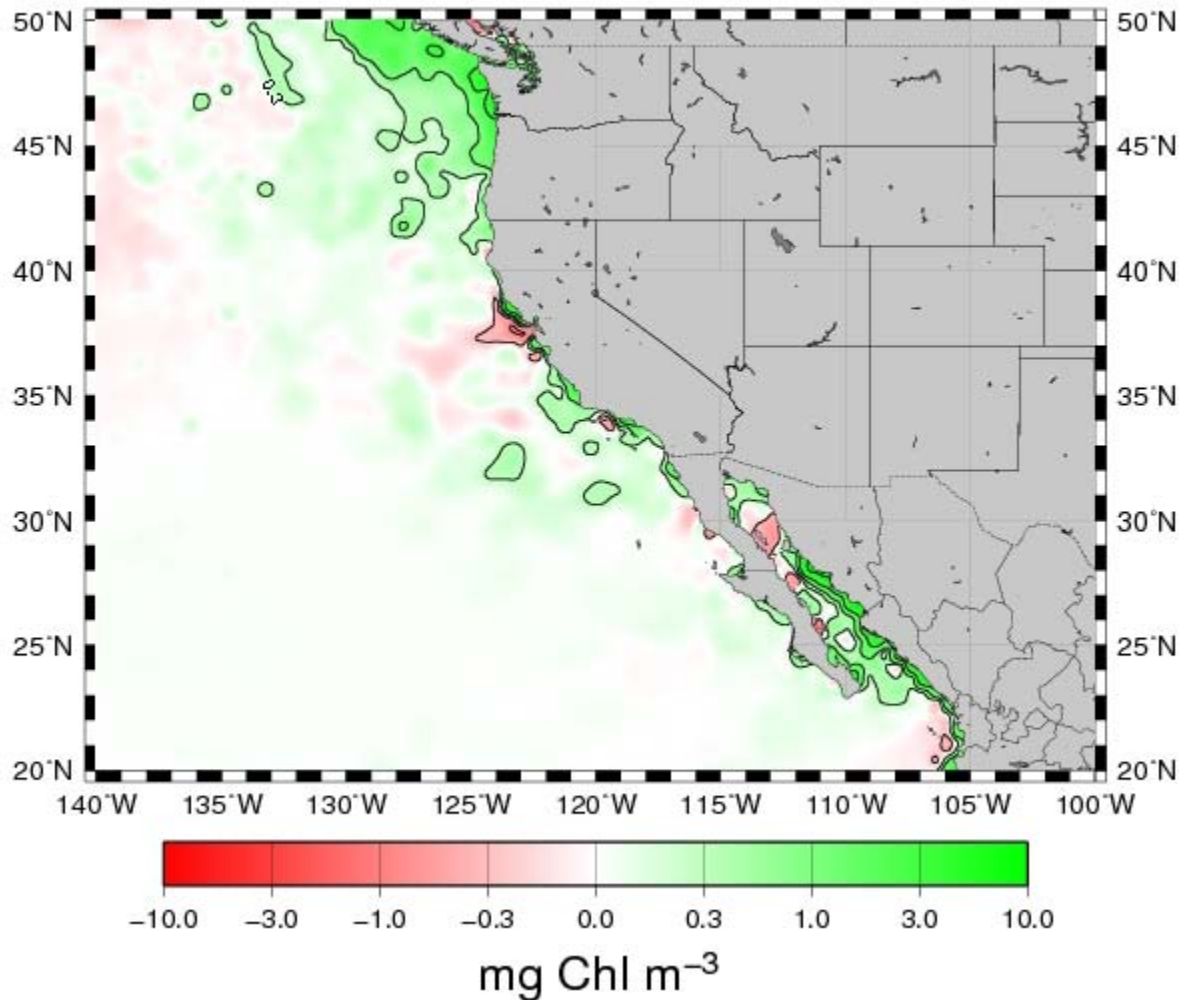
Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport at 50 meter depth from each location to its nearest coast point ($\text{m}^3/\text{s}/100\text{m}$ coastline). Anomalies are departures from the 1982-2004 base period pentad means.

- Area below (above) black line indicates climatological upwelling (downwelling) season.
- Climatologically upwelling season progresses from March to July along the west coast of North America from 36°N to 57°N.

Monthly Chlorophyll Anomaly

<http://coastwatch.pfel.noaa.gov/FAST>

MODIS Aqua Chlorophyll a Anomaly for January, 2009

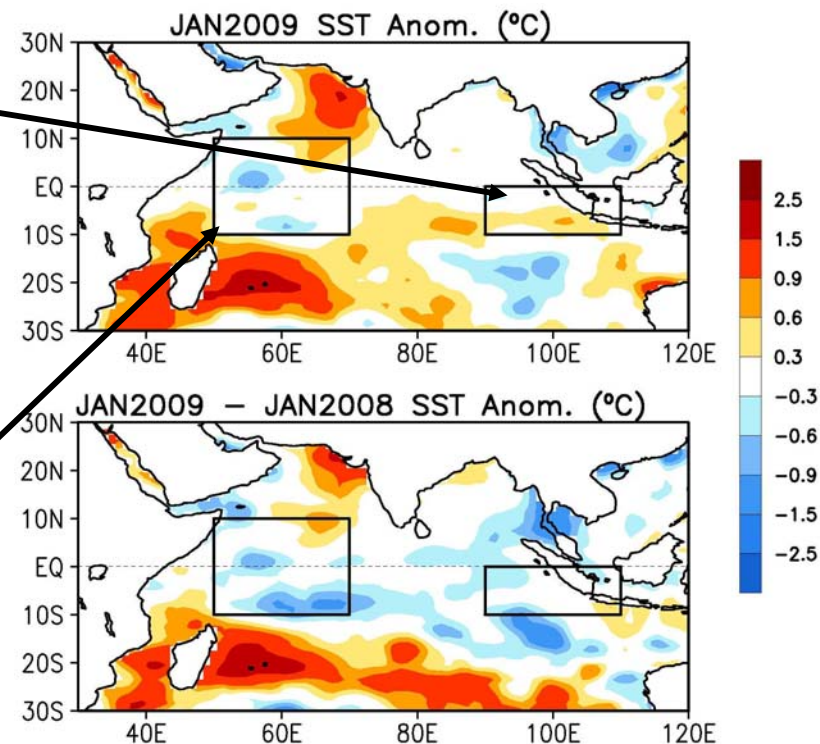
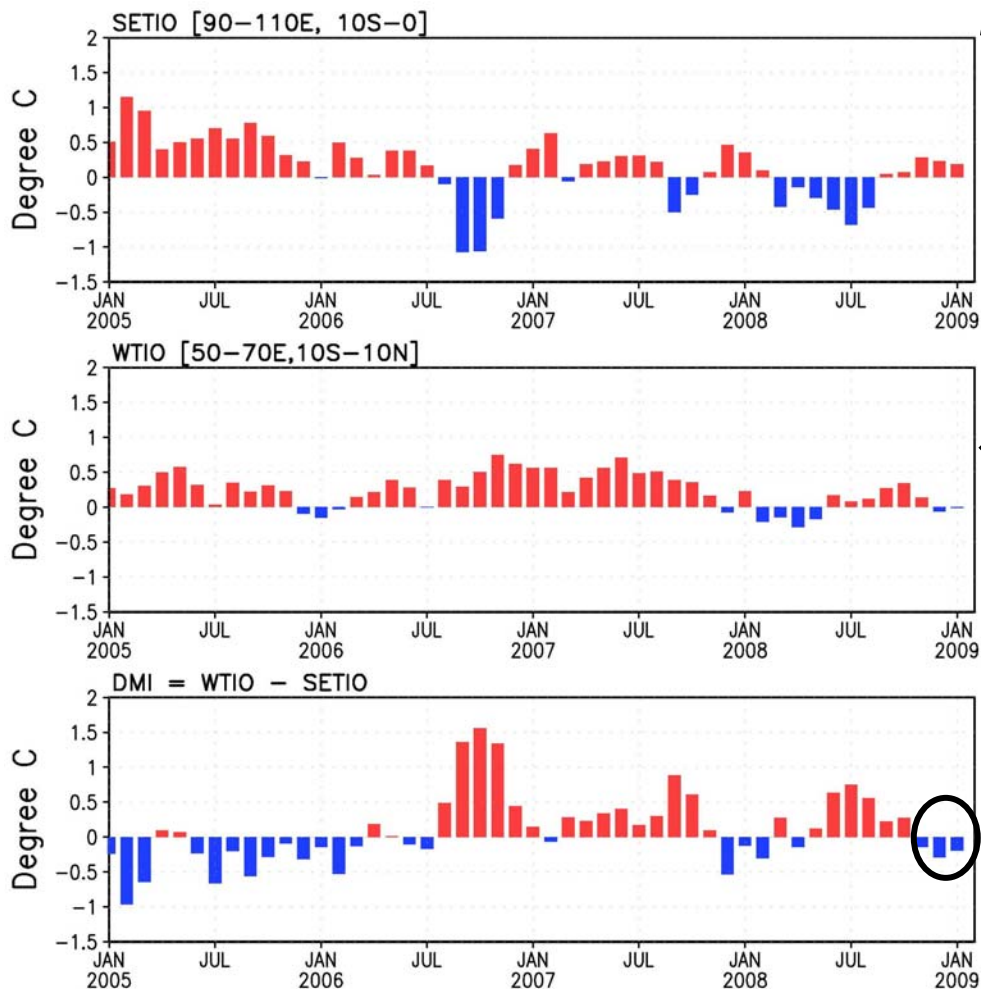


- Positive Chlorophyll anomalies presented along most of the western North America coast, consistent with above-normal upwelling.

Tropical Indian Ocean

Evolution of Indian Ocean SST Indices

Indian Ocean Dipole Mode Indices



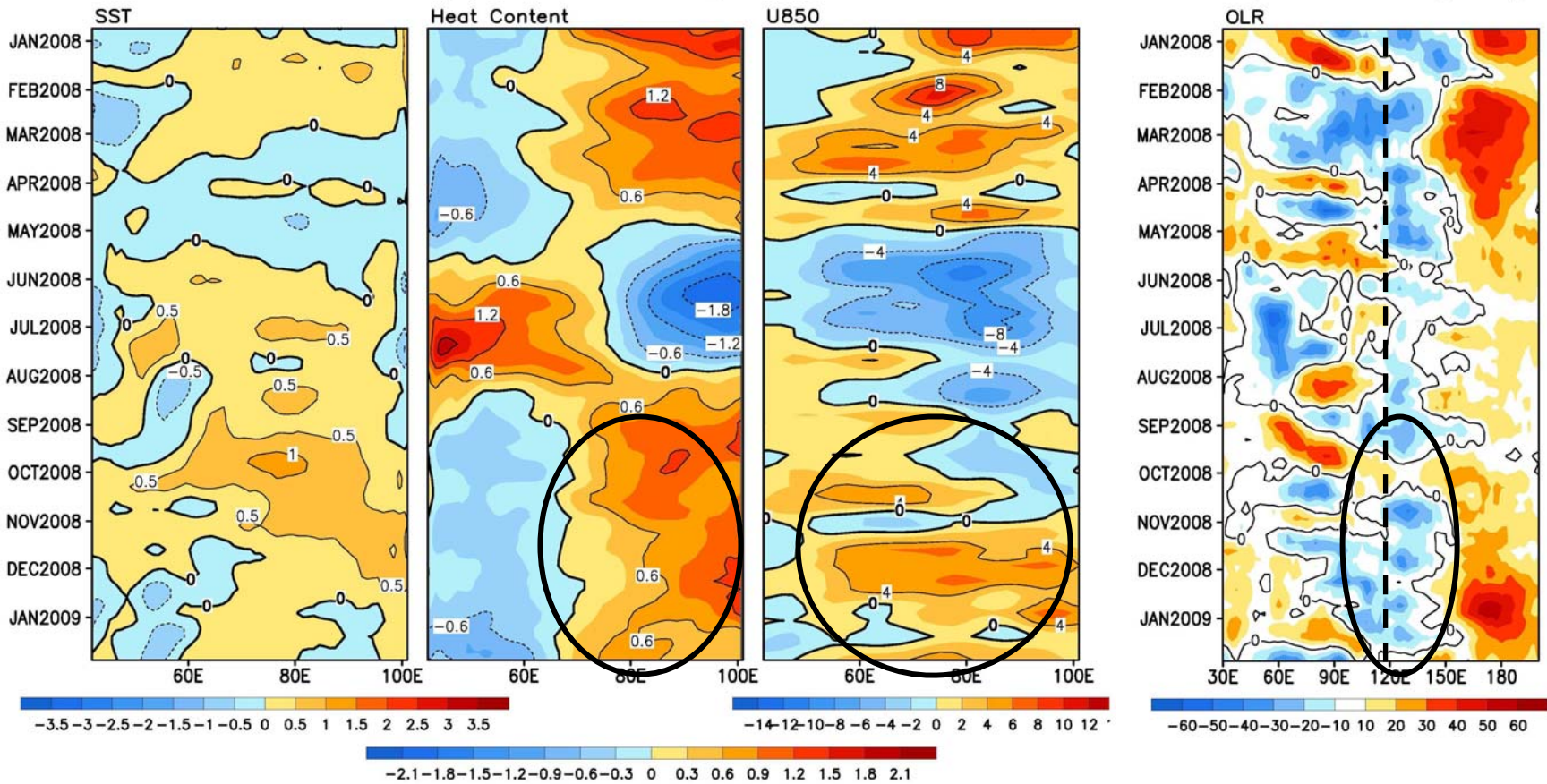
- Dipole Mode Index (DMI) and its eastern and western pole indices were all near-normal since September 08.
- Large positive SST anomalies presented in the south-western Indian Ocean.

Fig. 11a. Indian Ocean Dipole region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the SETIO [90°E-110°E, 10°S-0] and WTIO [50°E-70°E, 10°S-10°N] regions, and Dipole Mode Index, defined as differences between WTIO and SETIO. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

Recent Evolution of Equatorial Indian SST ($^{\circ}\text{C}$), 0-300m Heat Content ($^{\circ}\text{C}$), 850-mb Zonal Wind (m/s) and OLR (W/m^2) Anomalies

2 $^{\circ}\text{S}$ –2 $^{\circ}\text{N}$ Average, 3 Pentad Running Mean

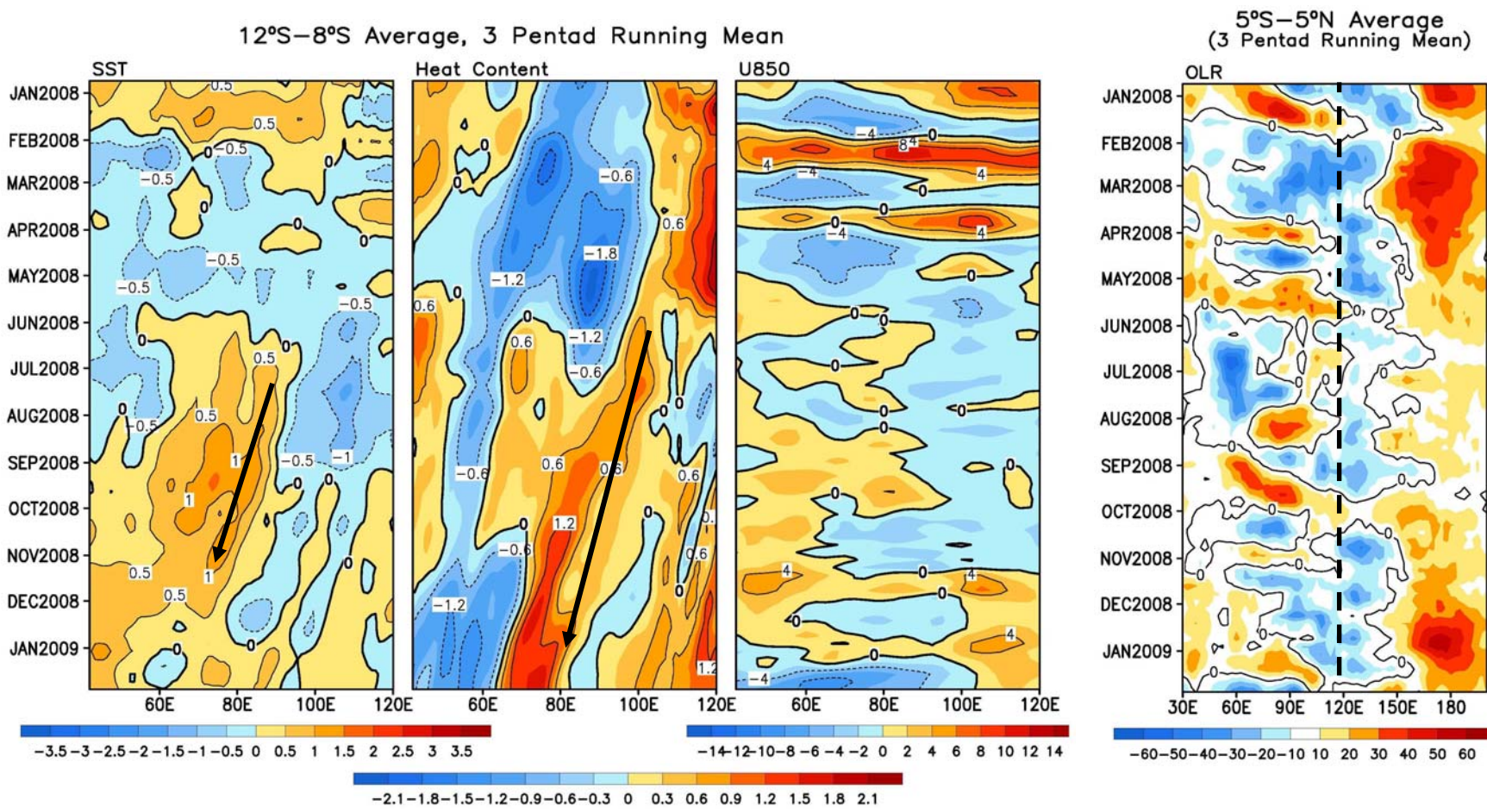
5 $^{\circ}\text{S}$ –5 $^{\circ}\text{N}$ Average
(3 Pentad Running Mean)



- Westerly wind anomalies since August were associated with the persistent enhanced-convection over the Maritime Continent.
- These westerly wind anomalies have suppressed the positive IOD that occurred in the early Northern Summer.

Fig. 13. Time-longitude section of anomalous pentad sea surface temperature (left), upper 300m temperature average (heat content, middle-left), 850-mb zonal wind (U850, middle-right) averaged in 2 $^{\circ}\text{S}$ -2 $^{\circ}\text{N}$ and Outgoing Long-wave Radiation (OLR, right) averaged in 5 $^{\circ}\text{S}$ -5 $^{\circ}\text{N}$. SST are derived from the NCEP OI SST, heat content from the NCEP's global ocean data assimilation system, and U850 from the NCEP CDAS. Anomalies for SST, heat content and U850/OLR are departures from the 1971-2000, 1982-2004, 1979-1995 base period pentad means respectively.

Recent Evolution of 10°S Indian SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s)



- Westward propagation of positive heat content anomalies persisted since June 08.

Fig. 14. Time-longitude section of anomalous pentad sea surface temperature (left), upper 300m temperature average (heat content, middle-left), 850-mb zonal wind (U850, middle-right) averaged in 12°S–8°S and Outgoing Long-wave Radiation (OLR, right) averaged in 5°S–5°N. SST are derived from the NCEP OI SST, heat content from the NCEP's global ocean data assimilation system, and U850 from the NCEP CDAS. Anomalies for SST, heat content and U850/OLR are departures from the 1971–2000, 1982–2004, 1979–1995 base period pentad means respectively.

Tropical Indian: SST Anom., SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Wind Anom.

- Positive SSTA in the south-western Indian Ocean, and Arabian Sea.
- Convection was enhanced (suppressed) in the Maritime Continents (south-eastern Indian Ocean).

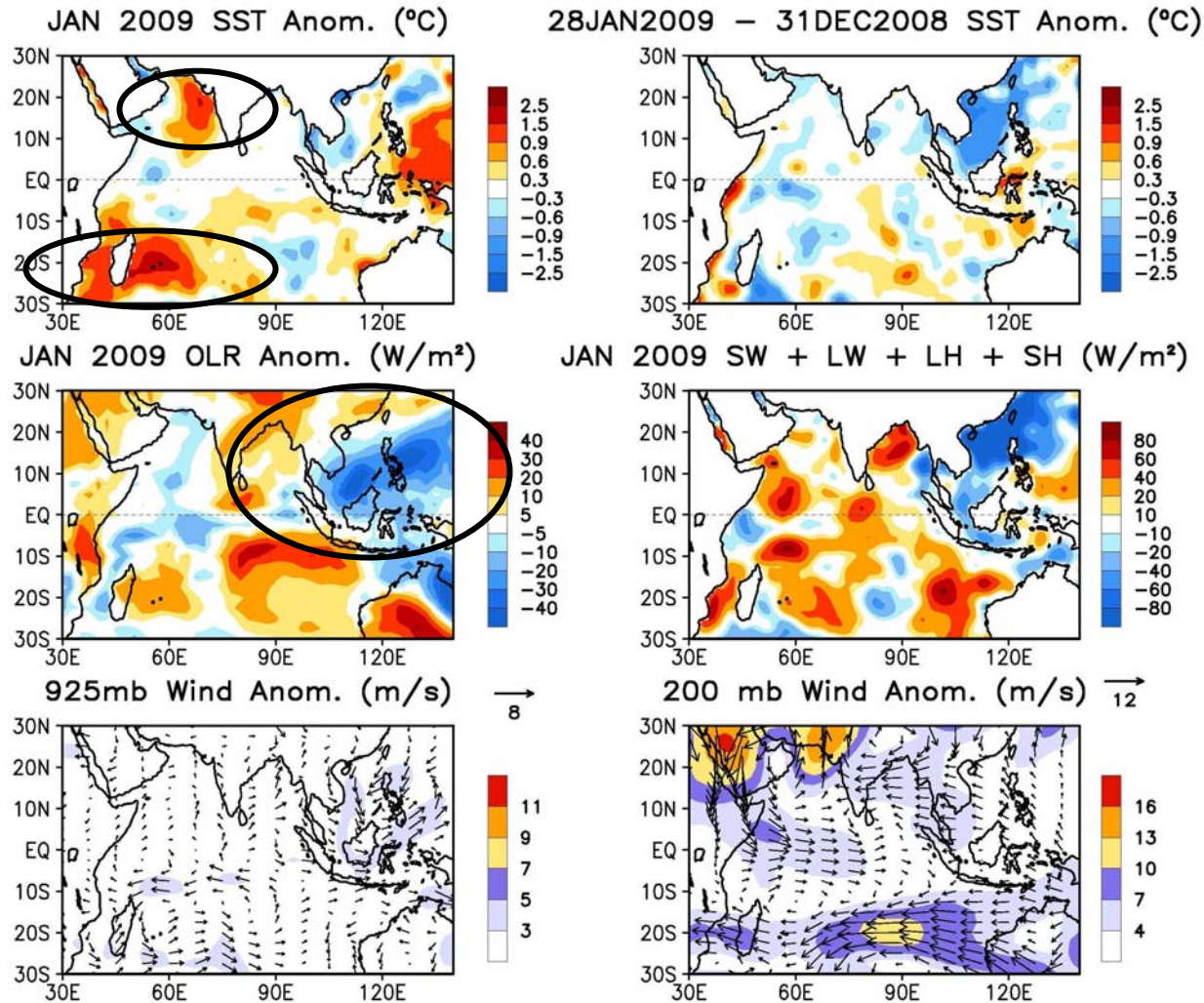


Fig. 12. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, winds and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1979-1995 base period means except SST anomalies are computed with respect to the 1971-2000 base period means.

Tropical Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

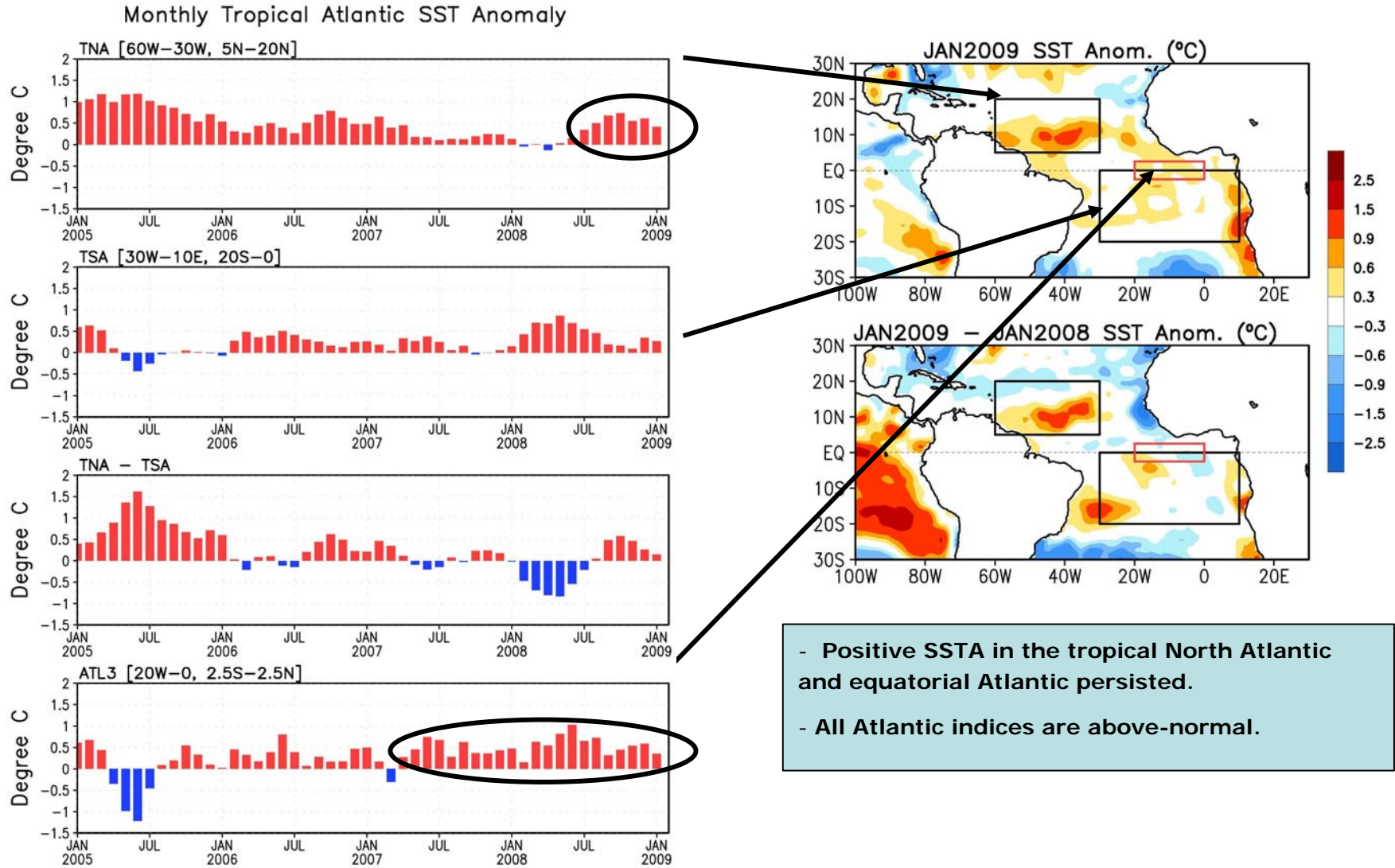
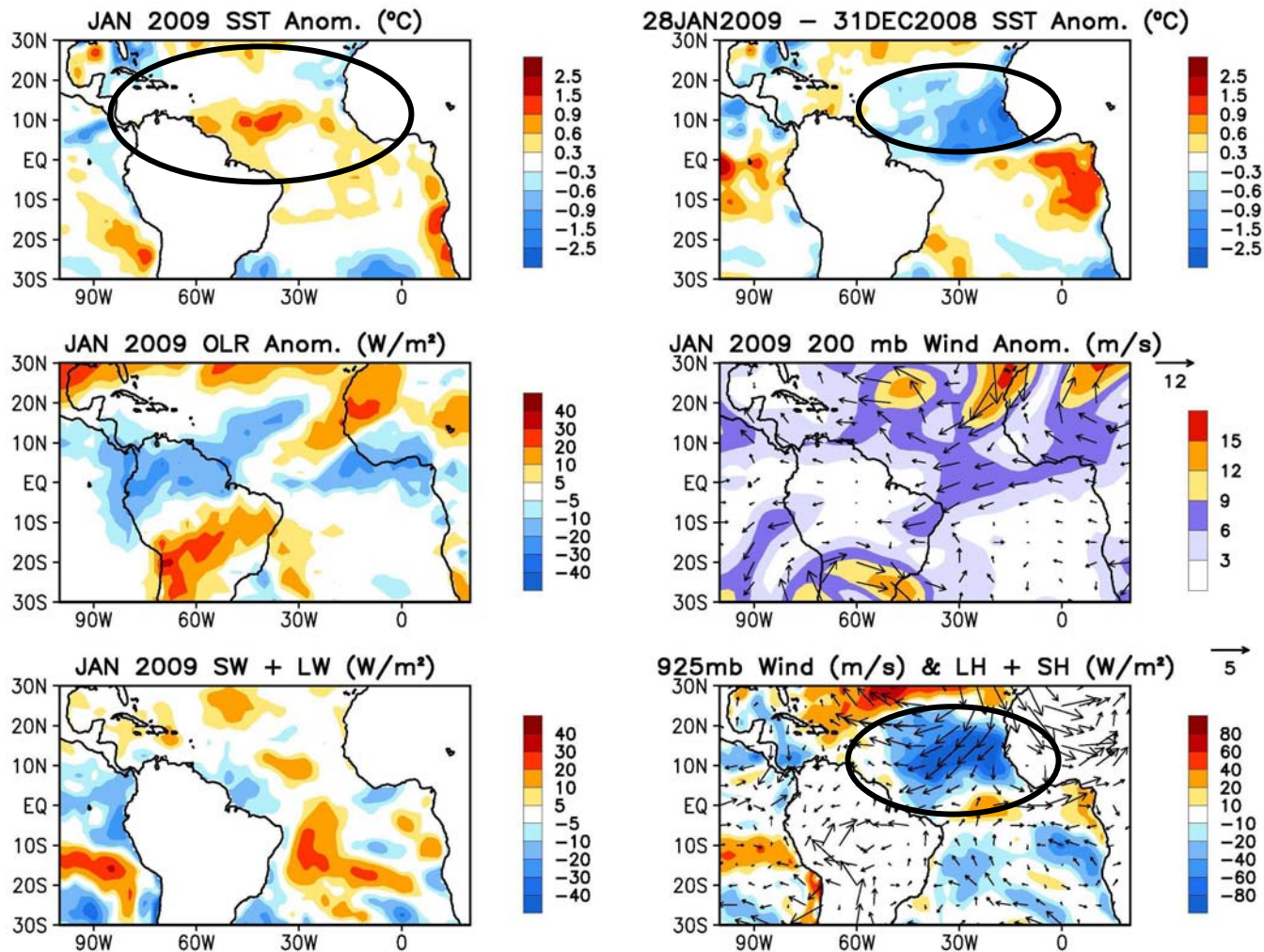


Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the TNA [60°W-30°W, 5°N-20°N], TSA [30°W-10°E, 20°S-0] and ATL3 [20°W-0, 2.5°S-2.5°N] regions, and Meridional Gradient Index, defined as differences between TNA and TSA. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

Tropical Atlantic:

SST Anom., SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, 925-mb/200-mb Winds



- SSTs cooled down in the eastern tropical Atlantic.
- Negative latent and sensible heat anomalies induced by strong northeast wind anomalies contributed to the SST cooling.

North Atlantic Ocean

North Atlantic: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx

- North Atlantic SST remains above-normal.
- SST cooled down along the eastern coast of North America in January 09, which was caused by surface heat fluxes.

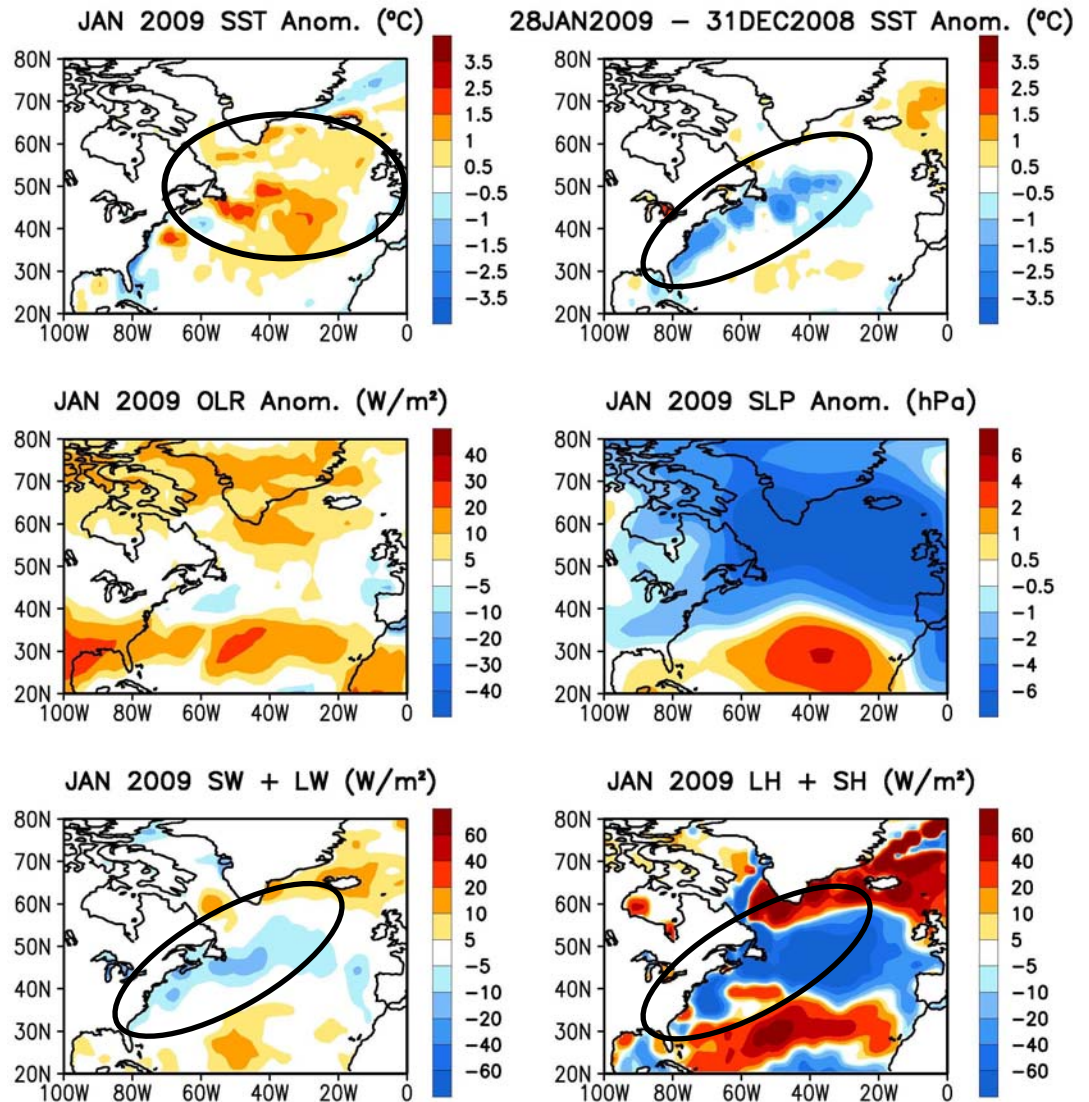
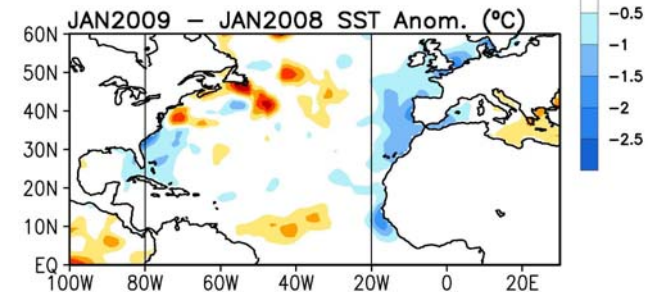
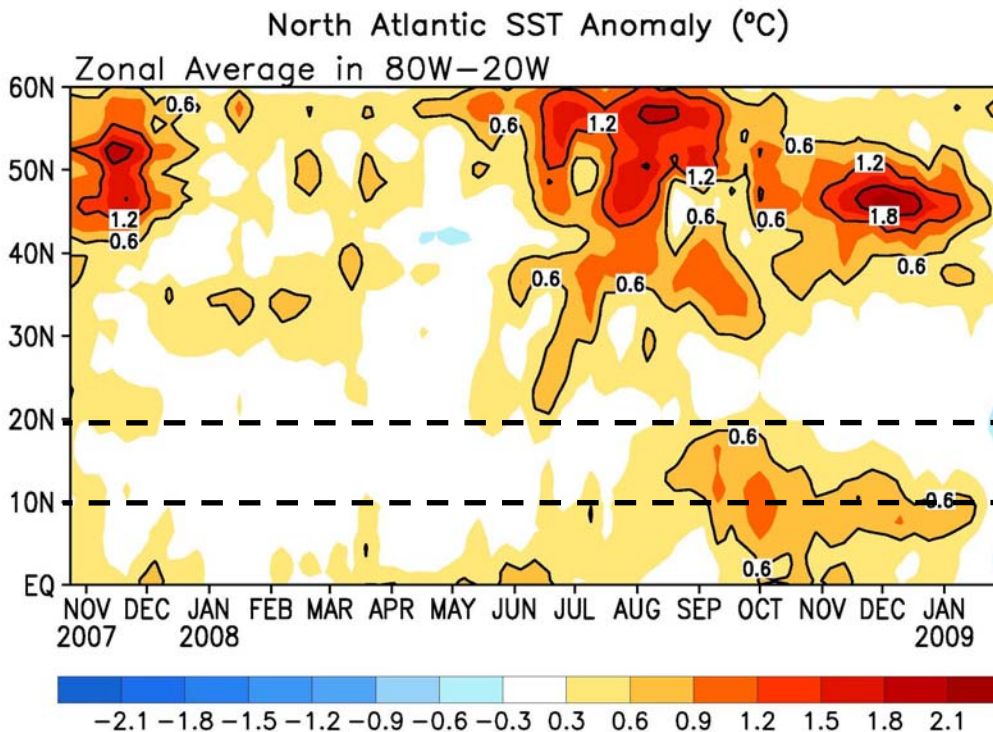
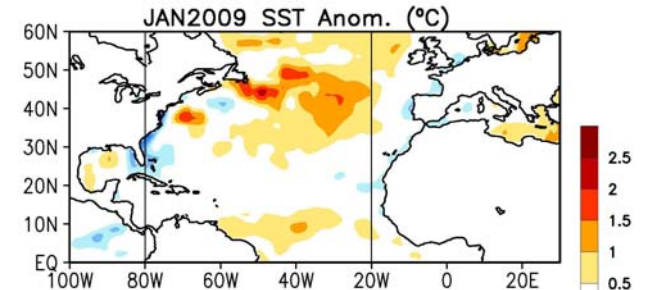
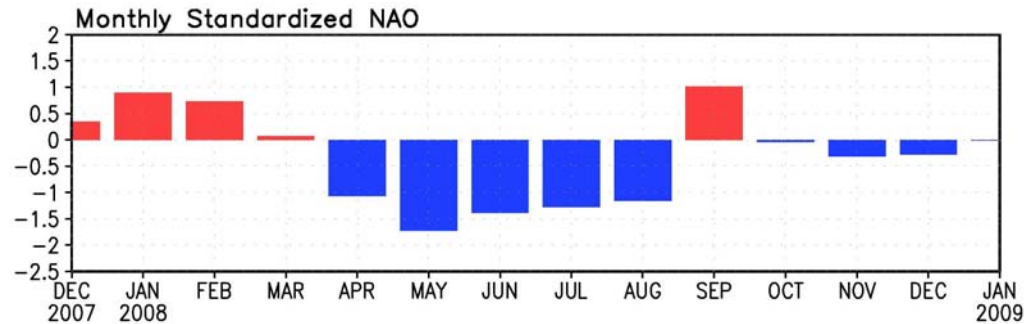


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible heat flux anomalies (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, sea surface pressure and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1979-1995 base period means except SST anomalies are computed with respect to the 1971-2000 base period means.

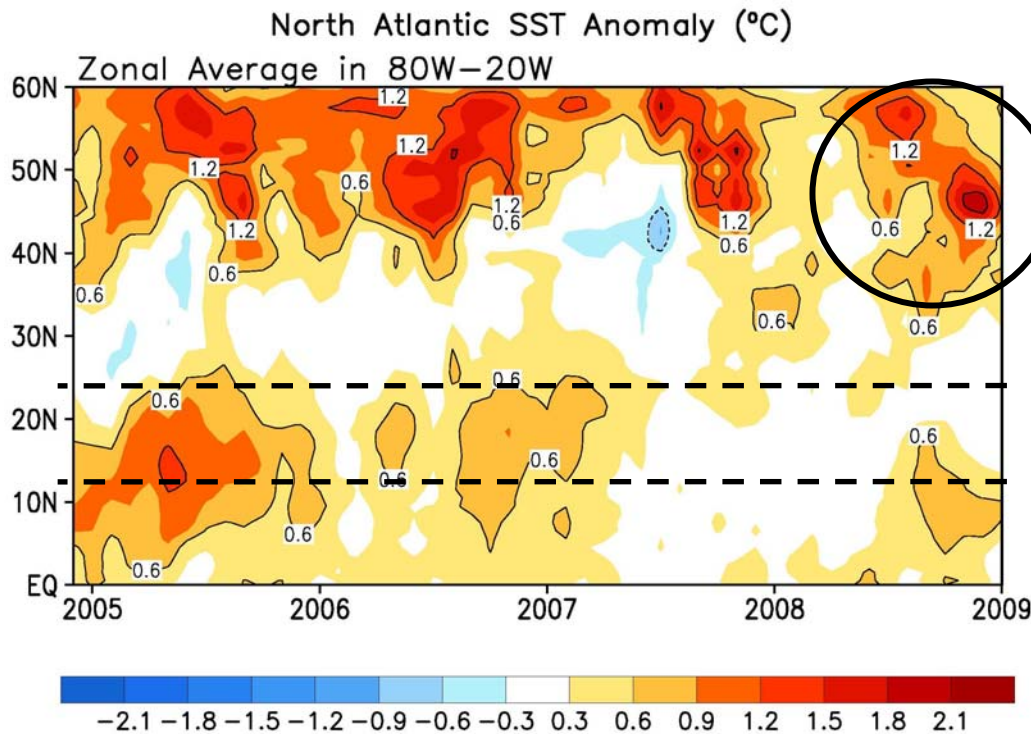
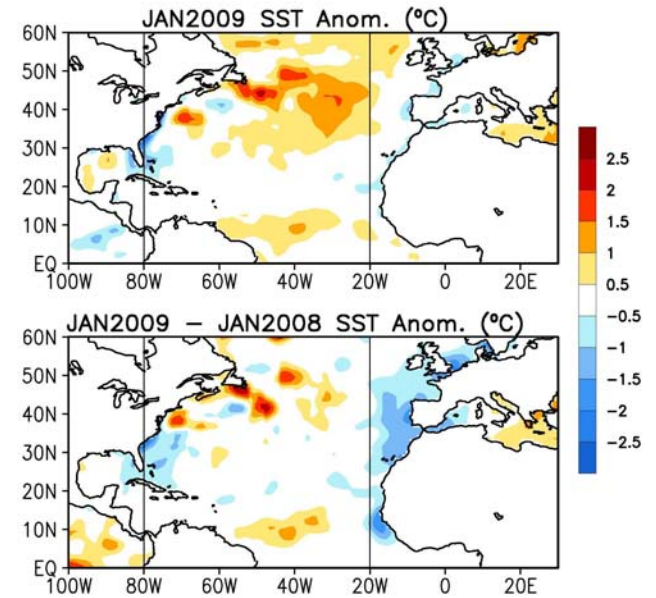
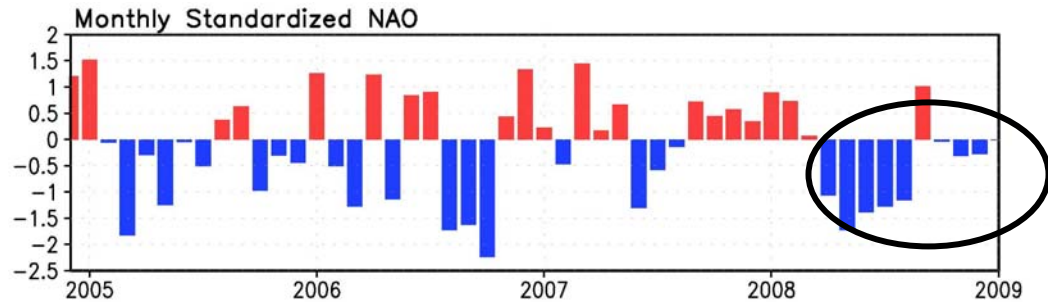
NAO and SST Anomaly in North Atlantic



- High-latitude North Atlantic SSTA are closely related to NAO index – negative (positive) NAO leads to SST warming (cooling).
- NAO was near-normal in January 09.
- Positive SSTA in the Hurricane Main Development Region were near-normal in January 09.

Fig. NA2. Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20°N-90°N (<http://www.cpc.ncep.noaa.gov>). Time-Latitude section of SST anomalies averaged between 80°W and 20°W (bottom). SST are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

NAO and SST Anomaly in North Atlantic



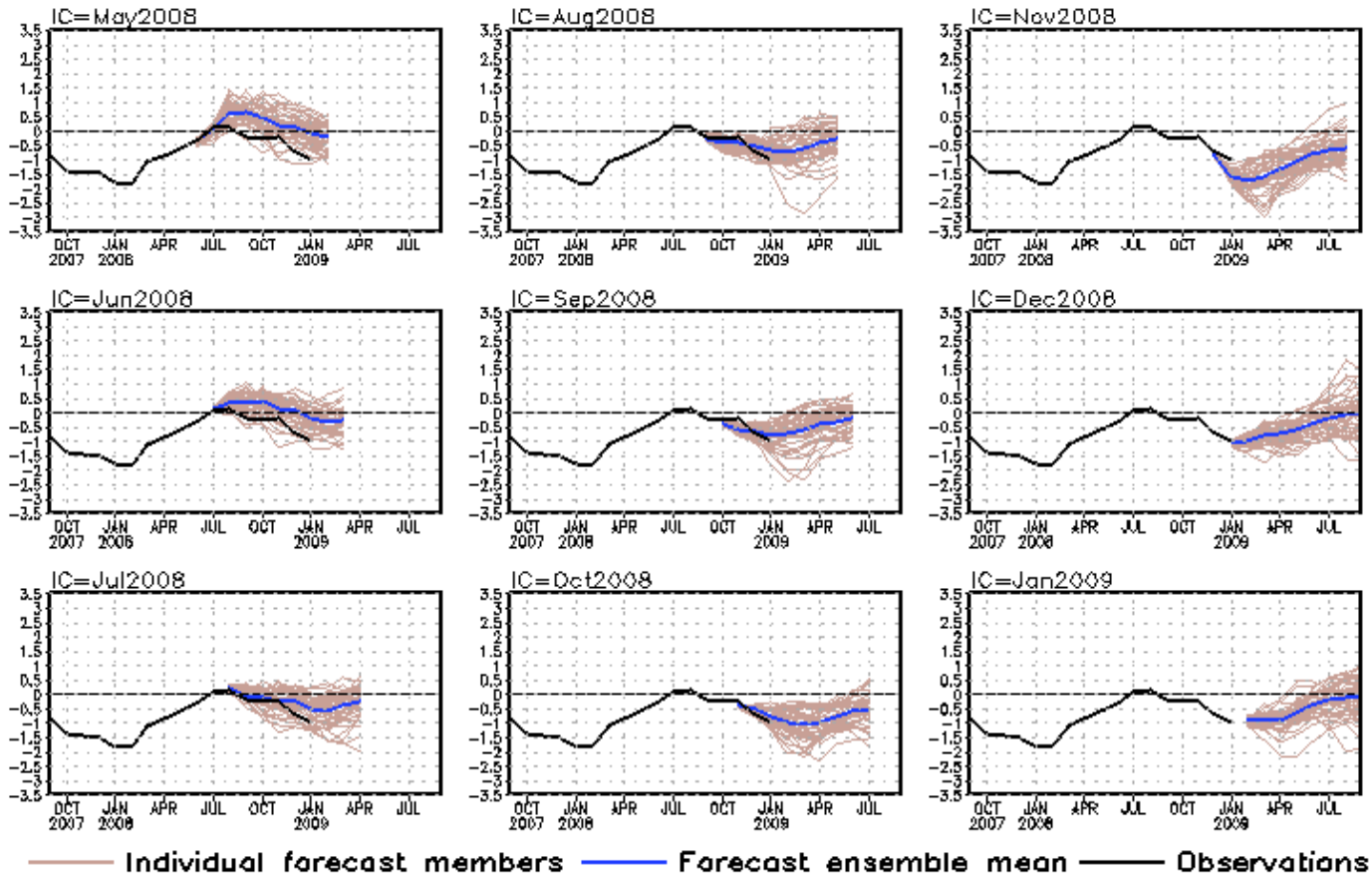
- North Atlantic SSTs have warmed up since June 2008 due to persistent negative NAO phase.

Fig. NA2. Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20°N-90°N (<http://www.cpc.ncep.noaa.gov>). Time-Latitude section of SST anomalies averaged between 80°W and 20°W (bottom). SST are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

CFS SST Predictions and Ocean Initial Conditions

CFS Niño3.4 SST Predictions from Different Initial Months

NINO3.4 SST anomalies (K)

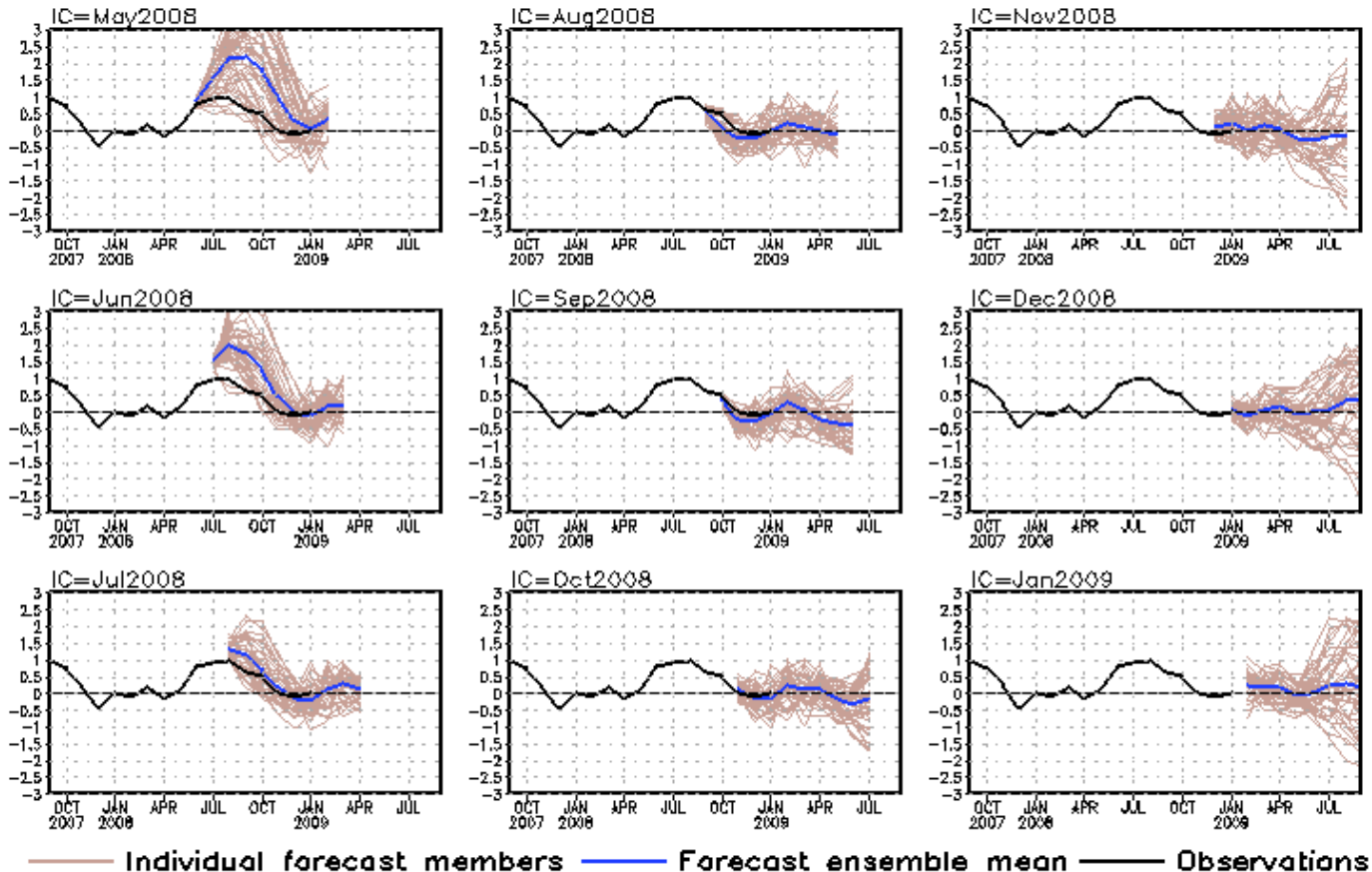


- Latest forecasts suggest that a weak La Nina will persist through Spring 09.

Fig. M1. CFS Niño3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labeled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). The hindcast climatology for 1981-2006 was removed, and replaced by corresponding observation climatology for the same period. Anomalies were computed with respect to the 1971-2000 base period means.

CFS DMI SST Predictions from Different Initial Months

Indian Ocean Dipole SST anomalies (K)



DMI = WTIO - SETIO
 SETIO = SST anomaly in [90°E-110°E, 10°S-0]
 WTIO = SST anomaly in [50°E-70°E, 10°S-10°N]

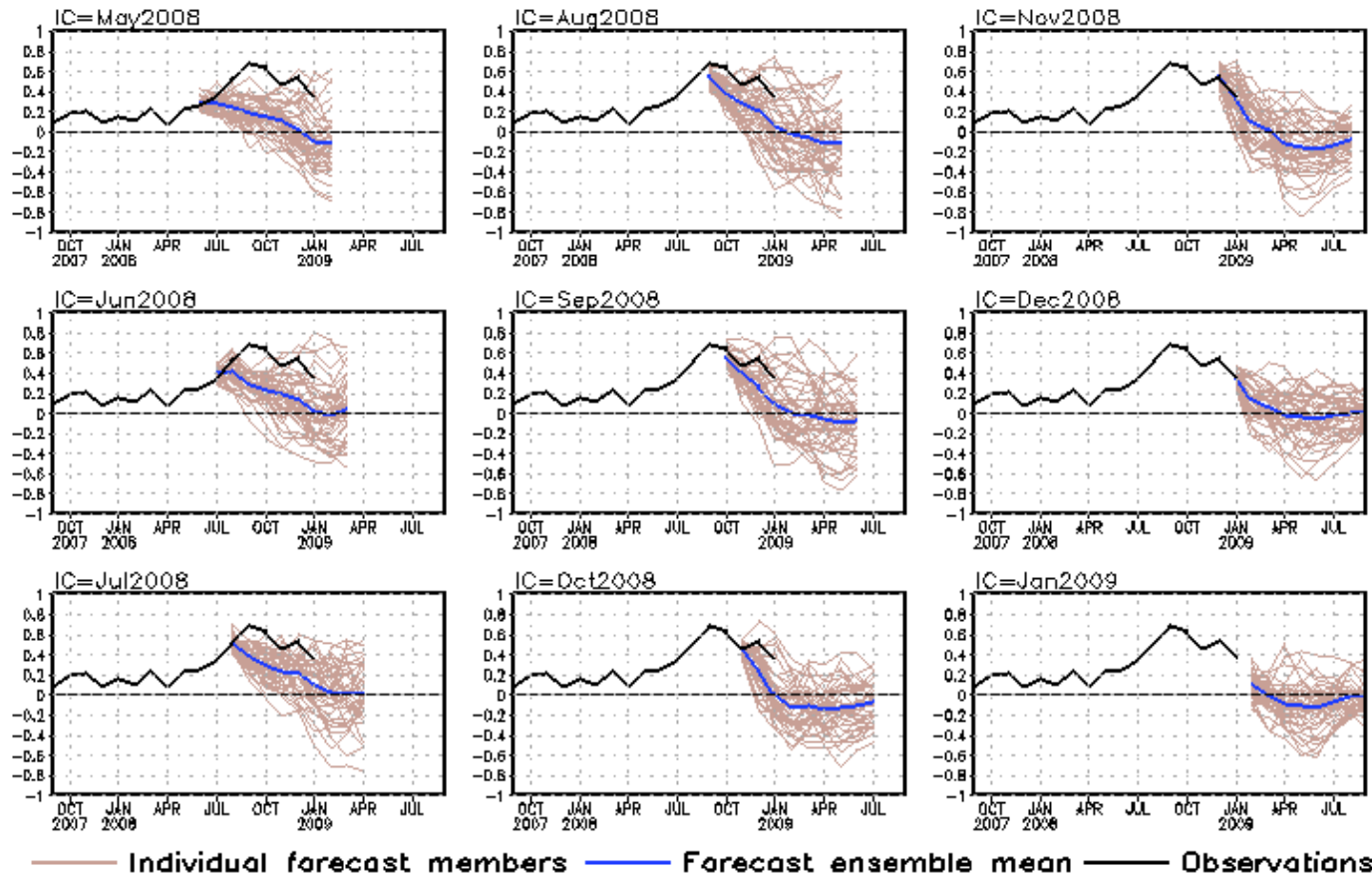
- CFS overestimated the amplitude of the positive IOD in May-Jun I.C.
- Latest forecasts call for near-normal conditions in next 6-9 months.

Fig. M2. CFS Dipole Model Index (DMI) SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labeled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). The hindcast climatology for 1981-2006 was removed, and replaced by corresponding observation climatology for the same period. Anomalies were computed with respect to the 1971-2000 base period means.

CFS Tropical North Atlantic (TNA) SST Predictions

from Different Initial Months

Tropical N. Atlantic SST anomalies (K)



TNA is the SST anomaly averaged in the region of [60°W-30°W, 5°N-20°N].

- CFS always damps SSTA in I.C., suggesting either the SSTA is unpredictable or the model has systematic errors in predicting summer SSTA in the Hurricane Main Development Region.

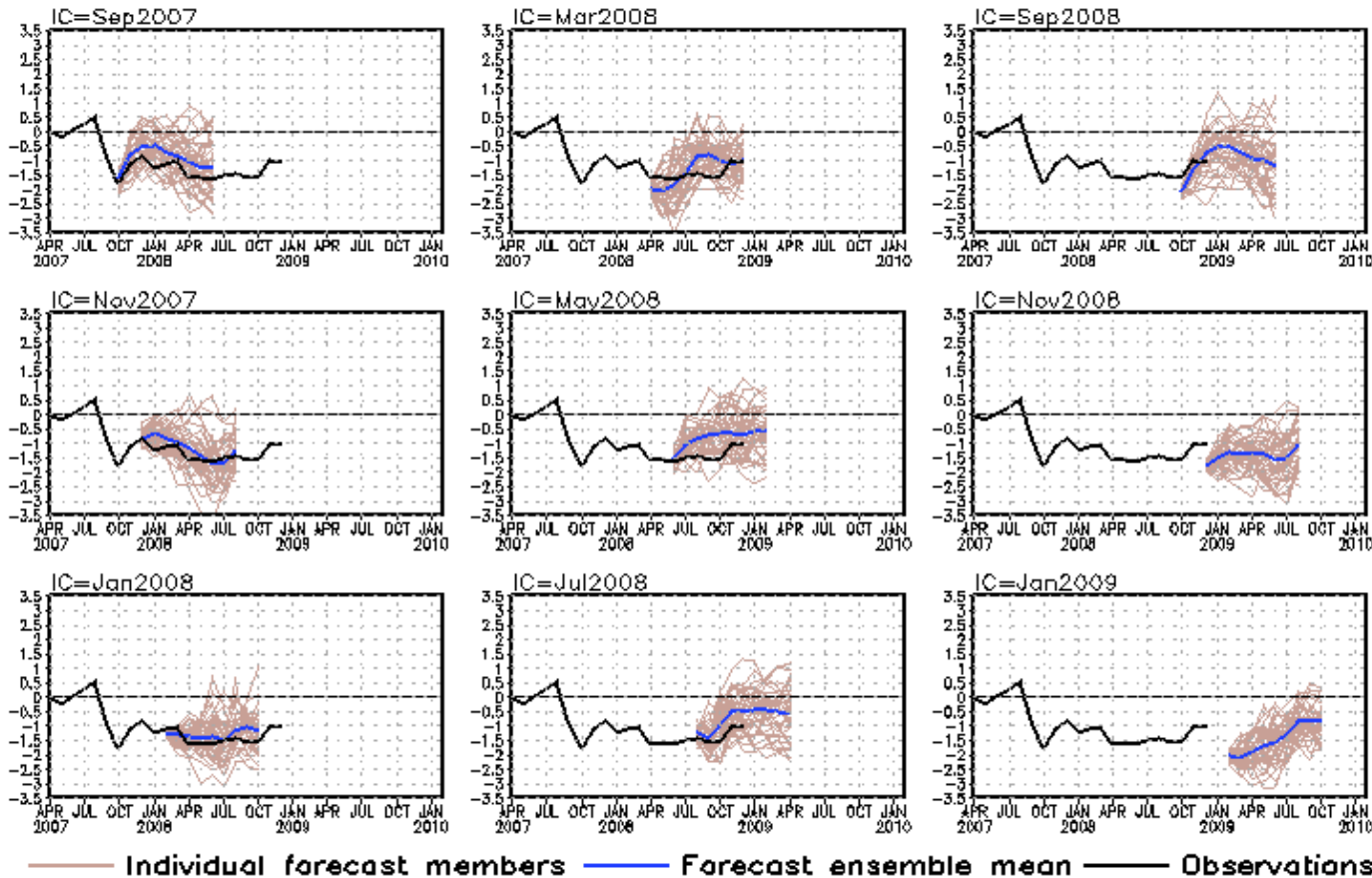
- Latest forecasts suggest that the current positive SSTA will dissipate quickly and return to near-normal conditions next month.

Fig. M3. CFS Tropical North Atlantic (TNA) SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labeled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). The hindcast climatology for 1981-2006 was removed, and replaced by corresponding observation climatology for the same period. Anomalies were computed with respect to the 1971-2000 base period means.

CFS Pacific Decadal Oscillation (PDO) Index Predictions

from Different Initial Months

standardized PDO index



PDO is the first EOF of monthly SST in the region of [110°E-100°W, 20°N-60°N].

- CFS SST anomalies are projected onto the PDO SST pattern (slide 16).
- CFS has forecast the recent negative PDO phase since July 07 I.C.
- Latest forecasts suggest that the current negative PDO will persist through summer 09.

Fig. M4. CFS Pacific Decadal Oscillation (PDO) index predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labeled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). The hindcast climatology for 1981-2006 was removed, and replaced by corresponding observation climatology for the same period. Anomalies were computed with respect to the 1971-2000 base period means.

Summary

- **Pacific Ocean**

- La Niña conditions ($\text{NINO3.4} < -0.5^{\circ}\text{C}$) persisted in January 09, and are expected to continue into Spring 2009.
- Negative PDO-like SST pattern has persisted in North Pacific for 17 months with yearly mean value as the lowest since 1971.
- Extremely strong above-normal upwelling has persisted along the west coast of North America for two months.

- **Indian Ocean**

- Positive SST anomalies presented in the southern Indian Ocean and the Arabian Sea.
- The tropical Indian Ocean SSTs are close to normal.

- **Atlantic Ocean**

- Positive SST anomalies presented in mid-latitude North Atlantic and tropical Atlantic.

- **Arctic Ocean**

- Ice concentration remains much below-normal, with the ice growth slowing down in later January.

Backup Slides

Data Sources and References

- **Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002)**
- **SST 1971-2000 base period means (Xue et al. 2003)**
- **NCEP CDAS winds, surface radiation and heat fluxes**
- **NESDIS Outgoing Long-wave Radiation**
- **PMEL TAO equatorial temperature analysis**
- **NCEP's Global Ocean Data Assimilation System temperature, heat content, currents (Behringer and Xue 2004)**
- **Aviso Altimetry Sea Surface Height**
- **Ocean Surface Current Analyses – Realtime (OSCAR)**

Please send your comments and suggestions to Yan.Xue@noaa.gov. Thanks!